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THE AUTOMOBILE

A PRACTICAL TREATISE ON
THE CONSTRUCTION OF MODERN MOTOR CARS
STEAM, PETROL, ELECTRIC AND PETROL-ELECTRIC

BASED ON LAVERGNE'S "L'AUTOMOBILE SUR ROUTE"

EDITED BY PAUL N.ooncree HASLUCK

NEW EDITION ENLARGED TO 832 PAGES COMPLETELY
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PREFACE TO NEW AND REVISED EDITION.

I OFFER this treatise as an up-to-date compendium of information on the construction of the modern automobile. Development has been astonishingly rapid in this new industry, and though the first edition of the present work was published only sixteen months ago, there has already arisen an urgent need for revising it. The present volume, however, is much more than a mere revised re-issue. The first edition was a considerably amplified translation of Gérard Lavergne's "Manuel Théoretique et Pratique de l'Automobile sur Route"; but of the 832 pp. comprising the present volume only about 300 had a place in the first edition, and still less than that number were directly derived from the French original. More than 500 pp. of the present work are new, and are concerned with recent developments in automobile practice. Many devices that are only of historical interest are at most merely mentioned here; and the few instances in which space is devoted to mechanisms now discarded will be found to describe some principle or device that is now employed in a more modern application. The illustrations, to the number of 533, were a marked feature of the first edition (the French original contained only 329), but the present work has 804, of which at least 500 are fresh; of that number 300 have been specially engraved. It is evident, then, that this new and revised edition is virtually a new book.

An attempt has been made to describe every noteworthy make of British and Continental car, or at least to indicate its salient features; whilst some of the most representative American constructions are also treated in detail.

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My thanks are due to many friends for the use of matter and illustrations which have enabled me to include accounts of the most recent developments in automobile practice; and in this connection special acknowledgment must be made to the respective proprietors of the *Automotor Journal* and the *Autocar*, on whose columns I have drawn freely, and who have gratuitously lent the blocks of selected illustrations. I am also indebted to Captain C. C. Longridge's paper "Oil Motor Cars of 1902," read before the Institution of Mechanical Engineers; to Mr. H. F. Joel's paper "Electric Automobiles," printed in the Proceedings of the Institution of Civil Engineers; and to Professor H. S. Hele-Shaw's report on traction resistances presented at the 1902 meeting of the British Association.

P. N. HASLUCK.

LA BELLE SAUVAGE, LONDON,
November, 1903.

PREFACE TO FIRST EDITION.

I HAVE used Gérard Lavergne's highly esteemed work, "Manuel Théoretique et Pratique de l'Automobile sur Route," as a basis for the present treatise, which, however, is distinguished in many important particulars from a mere translation.

In the endeavour to present a thoroughly up-to-date work, the original book has been re-written throughout in a more condensed style, and the space thus gained is here occupied by entirely new matter descriptive of mechanisms that have made their appearance within the last year or so. For instance, the chapters on boilers, steam motors, carburetters, petrol motors, steam and petrol cars have been re-cast and considerably amplified, quite a large proportion of the present text having had no place in M. Lavergne's treatise.

Important additions also have been made to the historical chapter, the early history of mechanical road locomotion in England being here treated in detail. Many of the tables of results of races, trials, and efficiency tests here given are not to be found in M. Lavergne's work, and this matter will, it is believed, be appreciated highly. Many of the original illustrations have been superseded by new ones, and a great number of additional blocks have been inserted; in fact, of the 536 illustrations included in this book about 200 are new, whilst some others have been considerably improved, neither trouble nor expense having been spared in preparing special reproductions of drawings to enhance the value of the text.

A serious deficiency of the original work was its lack of an index. In the present work an index containing more than 4,000 items is provided. The very considerable amount of labour spent in preparing it has been cheerfully undertaken, in the confident belief that a full index to the mass of information contained in the book cannot fail to be of considerable value to all who are interested in the automobile industry.

In his preface to the original work, the French author thus describes its scope and object: "Without wishing to disparage the merit of previous publications, it seemed that there was room for a general treatment of the subject Thus the work we present to the public interested in automobiles is synthetic. A brief historic notice forms an introduction to the agents, steam, oil, and electricity, from which mechanical cars derive their energy, and after a rapid examination of the latest possibilities of compressed or liquefied gas, hot water, acetylene, and alcohol, the work passes in review the elements that compose an automobile motor (with calculation of the power it must have to run a given car and the methods of measuring its force when constructed), gear for transmitting the movement of the motor to the car wheels, axles, wheels, tyres, springs, frame, body, brakes, and lubricators. This analysis having been made, the elements are grouped according to the chief types of existing cars. As these types are very numerous, only representative ones have been selected for detailed description; of others it suffices to point out the characteristic features. Then the notable results officially or otherwise confirmed are recorded, and, finally, attention is directed to the lines on which progress in the direction of increased efficiency is to be sought.

"This book does not pretend to teach constructors; the most it can do is to call their attention to points which they appear to have neglected, or perhaps altogether ignored. The large numbers who are embarking in the new industry may possibly through this account of what has been already done be spared some of those trials and labours which constitute the heavy tribute, in sheer loss, levied on human activity by what might be styled re-inventions.

"The book will show the engineer how the mechanism with which he is familiar is applied in motor construction, how the technical difficulties arising from this novel application may be overcome, and what yet remains to be done in this rapidly growing industry. Those who, not being engineers, have but a slight knowledge of mechanics, but who are nevertheless interested in automobiles, either because they desire to use them or because they see in them the possibilities of an industrial revolution, need no longer be discouraged by the apparent complexity of the subject, for the writer has endeavoured to make his descriptions as clear and as free from technicalities as the character of the subject would admit."

The Metric system of weights and measures is adhered to throughout this book, as being the system countenanced by scientists, and as the only one having even the possibility of becoming universal. This system is in general use all over the civilised world (the English-speaking countries excepted), whilst even in the United

States of America its use is legal, and in Great Britain is permitted. The whole system is based on the length unit known as the metre, which is nearly one ten-millionth part of the earth's meridian quadrant; the British equivalent of the metre is 39·37079 inches. It is convenient to give here the names of the several Metric units, their abbreviations, and their equivalents in British measures, though throughout this work the reader's requirements have been met by presenting all weights and measures in both Metric and British terms.

The abbreviations of Metric units given below are in accordance with a decision made by the International Committee of Weights and Measures, 1890. First is printed the unit in its unabridged spelling, then the abbreviation, and lastly the English equivalent, whose accuracy may be relied upon.

UNITS OF LENGTH. *Kilomètre*, km., = 0·62138 (nearly ⅝) statute mile, about 1093·6 yds. *Mètre*, m., = 39·37079 in., or 1·09363 yd. *Décimètre*, dm., = 3·93707 in. *Centimètre*, cm., = 0·3937 in. *Millimètre*, mm., = 0·03937 in.

UNITS OF SURFACE. *Mètre Carré or Square Metre*, m.^{2}, = 1·19603 sq. yd. or 10·76429 sq. ft. *Décimètre Carré or Square Decimetre* dm.^{2}, = 15·50059 sq. in. *Centimètre Carré or Square Centimetre*, cm.^{2}, = 0·155005 sq. in. *Millimètre Carré or Square Millimetre*, mm.^{2}, = 0·00155 sq. in.

UNITS OF VOLUME. *Mètre Cube or Cubic Metre*, m.^{3}, = 35·31658 cub. ft. or 220·09667 gall. *Stère*, s., same as cubic metre. *Décimètre Cube or Cubic Decimetre*, dm.^{3}, = 0·03531 cub. ft. *Centimètre Cube or Cubic Centimetre*, cm.^{3}, = 0·06102 cub. in. *Millimètre Cube or Cubic Millimetre*, mm.^{3}, = 0·00006 cub. in.

UNITS OF CAPACITY. *Litre* (same as Décimètre Cube), l., = 0·22009 gall. or 61·02705 cub. in. *Décilitre*, dl., = 0·022009 gall., or 0·17607 pt. *Centilitre*, cl., = 0·017607 pt., or 0·07042 gill. *Millilitre*, ml., = 0·00704 gill.

UNITS OF WEIGHT. *Tonne*, t., 0·9842 ton, about 2,204·6 lb. *Quintal Métrique*, q., = 220·46212 lb. *Kilogramme*, kg., = 2·20462 lb., that is 2 lb. 3 oz. 4·38 dr. avoirdupois. *Gramme*, g., = 5·64383 dr. avoirdupois, 15·43234 grn. troy, or 0·03215 oz. troy. *Décigramme*, dg., = 1·54323 grn. troy. *Centigramme*, cg. = 0·15432 grn. troy. *Milligramme*, mg., = 0·01543 grn. troy.

UNITS OF WORK. The French *Force de Cheval-Vapeur* is equivalent to 0·9863373 of Watt's horse-power, adopted in Great

Britain and in the United States, which unit is defined as 550 foot-pounds (ft.-lb.) per second, or 33,000 ft.-lb. per minute. The difference, therefore, between the two units amounts to but little more than 1·36 per cent. in favour of the British unit, and in most cases this difference can be quite ignored. In this work, "Force de Cheval-Vapeur" and "Horse Power" (h.p.) are considered as identical except where peculiar conditions render distinction advisable. The unit *kilogrammètre* (kgm.) is the metric representative of foot-pound (ft.-lb.) in the British system; the metric unit is defined as the work done in raising 1 kg. a vertical distance of 1 m. and the British unit as the work done in raising 1 lb. a vertical distance of 1 ft.; thus 1 kgm. = 7·23314 ft.-lb.

COMPOUND UNITS. Most, if not all, of the engineering terms employing metric units have convenient English equivalents; thus so many "grammes or kilogrammes per square millimetre" is the corresponding expression to so many "pounds per square inch": 1 g. per mm.^{2} or 1 t. per m.^{2} = 1·422 lb. per sq. in.: 1 kg. per mm.^{2} = 1,422·282 lb. or 0·63494 ton per sq. in.; 1 g. per cm.^{2} = 0·01422 lb. per sq. in.; 1 kg. per cm.^{2} = 14·22282 lb. per sq. in.

Simple arithmetical calculations suffice for the conversion of these terms when once the value of the several units has been ascertained, and even much of this simple arithmetic can be dispensed with if a book of tables be consulted.

It is a pleasing duty gratefully to acknowledge my obligation to the proprietors of *The Automotor Journal*, 44, St. Martin's Lane, London, W.C., who have permitted me to use unreservedly any of the illustrations, and to excerpt any of the matter, that have appeared in that journal, and have gratuitously lent the blocks of selected illustrations, thus affording the opportunity to incorporate with the original book important additions and records of the most recent developments in automobiles.

P. N. HASLUCK.

LA BELLE SAUVAGE, LONDON,
August, 1902.

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THE AUTOMOBILE.

CHAPTER I.

EVOLUTION OF THE AUTOMOBILE.

THE automobile, which now is developing with such rapidity, is not—at least as far as the employment of the steam engine is concerned—so novel a vehicle as many people believe. It already has a long history, which deserves to be epitomised, because in it are successively revealed most of the parts whose combination constitutes the modern steam carriage.

Speculations upon the possible road use of fire- and steam-engines were made in England by Roger Bacon (1214-1294), and in the year 1619 a patent granted to Ramsay and Wildgoose had as part of its subject, "drawing-carts without horses." Already spring power had been tried in Germany, and wind-driven vehicles in the Netherlands.

By letters patent, dated October 10th, 1644, Louis XIV. granted to "Jean Theson the privilege of employing a little four-wheel carriage set in motion without any horses, but merely by two men seated"; and the Royal almanack of the period states that in the year 1748 Vaucanson, in the presence of Louis XV., drove "a carriage with clockwork springs," but in respect of which no details are given. It is, however, another Frenchman, Nicholas Joseph Cugnot, who should be regarded as the inventor of the steam automobile. In 1769 he constructed, with State funds placed at his disposition by the Duc de Choiseul, the first steam trolley, which the next year was followed by another somewhat further developed. This second trolley, a model of which, belonging to the Conservatoire des Arts et Métiers, was exhibited at the

Tuileries in June, 1889, is represented by Fig. 1. A kind of boiler, A, 1·27 m. (4 ft. 2 in.) in diameter, heated by a fire below, supplied steam to a four-way cock, B, which brought the two cylinders C, 33 cm. (13 in.) in diameter, into communication alternately with the boiler and with the exhaust. The movements of this cylindrical slide valve were caused by a somewhat complicated combination of connecting rods and catches. The possibility of changing the position of the latter might strictly have been utilised to vary the expansion of steam, though it is not thought that Cugnot ever had such an idea. The movement of the pistons was transmitted to the driving axle by means of two ratchet wheels, D, set in motion by rods corresponding to the two pistons, by aid of the arms E, furnished with pawls. This device could easily be employed to drive the wheel backwards simply by changing the pawl to the opposite side of the notch; in fact, the ratchet wheels turned in either direction according as the pawls acted upwards or downwards. This system was, until recently, employed in a simplified form by certain constructors, particularly by Brouhot, of Vierzon, who found in it the advantage of not requiring differential gear, as that part is named which makes the driving wheels independent in turning. Cugnot did not require independent wheels, because on his driving axle there was only one wheel; this was also used for steering, and at the same time he avoided a difficulty that was a stumbling-block to inventors until Rudolph Ackermann overcame it by the invention of a double-pivoted axle which enabled the steering wheels to be worked without disfiguring the frame of the carriage. It is needless to remark that with a single wheel for driving and steering, Cugnot's trolley was deficient in two valuable points, namely, power and stability. The frame designed

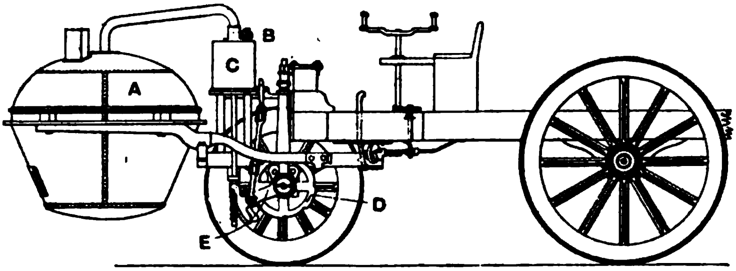


Fig. 1.—Cugnot's Steam Trolley.

to carry a cannon or any other similar weight was formed by two strong wooden side beams with tie bars. At the back it rested on a carrying axle, and in front was joined to a wrought-iron frame supporting the engine and boiler, the latter projecting over the front. The frame rested on the driving axle through the intermediary of bronze bearings. The whole could turn round a vertical pivot under the action of gearing worked by a handle in front of the driver's seat. In the few trials to which it was subjected the trolley carried a load of 2,500 kg. (2½ tons) at a speed of 5 km. (3 miles) per hour; but it had to stop every quarter of an hour for the boiler to be refilled with water and to get up sufficient steam pressure. The experiments were brought to an end by a false move, which caused the trolley to run into and knock down a wall, thus giving an obvious but unfortunate proof of its power. The chief defect of the Cugnot vehicle was its boiler: none the less it marked an interesting step in quite a new direction, which did not pass unnoticed by General Bonaparte on his return from Italy. At his initiative a Commission of the Institute was appointed to investigate the invention, but his departure for Egypt delayed and finally prevented the realisation of this plan. These efforts awakened no response in France, and it is in England that the growth of the automobile must be followed; but our first remarks will have to be of a retrospective character.

Sir Isaac Newton (1642–1727) is reported to have invented a steam carriage, the motor in which was a kettle with its spout turned to the rear, and this, being provided with a horizontal jet-piece, formed a single-jet reaction apparatus, similar to the present-day steam toys. Newton's motor was a Hero's steam engine (invented in the 2nd century B.C.), according to Beaumont's Cantor Lectures (1895), and was inferior to Giovanni Banca's steam turbine, made in the year 1629. Newton seems to have been forestalled by Father Verbiest, a missionary at Pekin, China, who placed an æolipile with jets playing on a revolving winged wheel geared to the wheels of a car. About the end of the 17th century and the beginning of the 18th Papin, Savery, and others made suggestions, which, however, do not appear to have been of much value. Dr. John Robison (1739–1805) suggested to James Watt, in 1759, it is said, the possibility of applying steam to carriage propulsion; but Watt did not encourage the scheme, either to Robison or, in later years, to Dr. Erasmus Darwin (1731–1802), Matthew Boulton (1728–1809), Small, Moore, and William Murdock (1754–1839), the last-named of whom had made a really successful locomotive. James Watt himself, in 1784, patented an invention for propelling vehicles by steam — an invention never brought to fruition. William Murdock, Watt's pupil, made, in 1785, a miniature tricycle having a steam cylinder less than 20 mm. (·787 in.) in diameter, and a piston stroke of little more than 50 mm. (1·97 in.). In 1790 Nathaniel Read, of Massachusetts, patented a steam carriage with two cylinders, whose pistons were connected to racks which moved pinions on the driving axles, ratchets preventing motion except in one way. This system of rack and ratchet has been revived several times. In Read's carriage the exhaust jets were turned rearwards, thus acting as additional propellers; and as the exhaust pressure probably was nearly boiler pressure at the moment of release, each jet would have been as good as Newton's jet, which it resembled in principle. Beaumont remarks that Read's boiler, like those of many who followed him, bore no relation to the capacity of the cylinders, except that of equality in steam space dimensions.

William Symington (1764–1831) patented a steam road carriage in 1786, and a model of the carriage made by him had a cylindrical boiler, with a lever safety-valve, supplying steam to the cylinder of an atmospheric condensing engine whose piston-rod communicated motion by means of a rack and ratchet wheel. This did not accomplish anything, other than what the rack and ratchet system could have done; but Symington's invention certainly was better than some contrivances which followed it.

The American inventor Read has already been mentioned, and another is Oliver Evans, who, in 1787, was the first to obtain the right in Pennsylvania and Maryland to operate steam road wagons, and who, in 1805, built a combined boat and road wagon. In France a vehicle of the same kind—a small steamboat on wheels—was built by Charles Dallery.

An advance on any of the foregoing was made by Richard Trevithick (1771–1833), who, with his friend Vivian, patented a steam carriage in 1802; gearing connected the crank-shaft with the driving wheels, and a flywheel was placed on the former. The carriage ran several journeys, the speed being as great as 16 km. (10 miles) an hour; but at the end of three years the partners had spent all their money on it, and it was sold for driving a hoop-rolling mill—work which it did satisfactorily for many years. The Trevithick vehicle was the first example, as far as automobiles are concerned, of transmitting power by gearing.

The first steam carriage having comfortable accommodation for passengers was designed by Julius Griffiths, and in 1821 built in the works founded by Joseph Bramah (1748–1814). The boiler had superposed rows of horizontal tubes, in which the water was vaporised and superheated: it is the oldest example of tubular boilers now so widely known. After acting in the two vertical cylinder engines which work the driving axle, the steam was condensed in a set of thin tubes that became cold in contact with the air, and returned to the boiler. Considering the date, this arrangement is very remarkable, viewed as a good theoretic utilisation of fuel and water, but practically it was defective. The water-tubes in the boiler were 61 cm. (2 ft.) long and 3·8 cm. (1·5 in.) in diameter, and were flanged to flat, vertical water chambers, which were connected across the top by transverse and longitudinal tubes forming the steam receivers, and to some extent superheaters. The cross tubes numbered 114, and their heating surface was about 8·26 $m.^2$ (89 sq. ft.), the total heating surface, including that of the water chambers, being from 10·2 to 11·1 $m.^2$ (110 to 120 sq. ft.). Boiler and motor were placed on springs on a rear platform, and the vehicle body, resembling that of a stage-coach, rested on springs on two beams supported by the axles. The rear axle carried the driving wheels, to which a number of gears, each giving one rate of speed, transmitted motion from the two steam pistons. The front axle was for steering as an ordinary fore-carriage, and was surmounted by the driver's seat. The failure of the boiler of course involved the failure of the whole vehicle, which did not have a practical road trial.

During the first quarter of the 19th century the fallacy was generally entertained that the adhesion of ordinary wheels was insufficient for traction purposes, and many arrangements were suggested for substituting for wheels a system of propulsion by mechanical legs and feet in rough imitation of animal action. Naturally, these push-foot schemes were found impracticable, but the carriage on this system patented in 1824 by David Gordon received much attention. The Gordon automobile

(Fig. 2) was suggested, evidently, by Brunton's locomotive, invented some years previously. The motive power was required to drive six regular hinged feet, whose purpose was to propel the vehicle in the same way as a horse's feet work, feet being arranged under the car in pairs on each side and in the centre. Stephenson had not then demonstrated the efficacy of adherence, otherwise the push-foot delusion would not have gained serious consideration.

A departure from previous methods was made in 1824 by W. H. James, who then patented a steam carriage in which the engines were not connected to the road wheels. He employed two tubular boilers, formed of concentric tubes, whose capacity was better proportioned to the size of the engine than in former attempts made by other inventors. The four cylinders were each 8·9 cm. (3·5 in.) in diameter; pistons were coupled in pairs to the two parts of a crank-shaft, upon each of which a back road wheel was keyed; thus the two wheels were independent of each other. A regulator distributed the steam to the two pairs of cylinders according to the work which fell to each wheel.

The boiler in the James vehicle (says Beaumont's Cantor Lectures) consisted of a number of rings of tubes, connected together and placed one outside the other so as to form a series of annular spaces, alternately, of tubes, about three-fourths being filled with water and heated gases; the fire was in the central ring of tubes, this central ring being 1 m. 37 cm. (4 ft. 6 in.) long, and 53·34 cm. (1 ft. 9 in.) in diameter. The water tubes in the boiler were of 2·54 cm. (1 in.) gaspipe, and gave much trouble; but in spite of all defects a car built on this system, and weighing less than 4½ tons, ran from Epping Forest to London with only one boiler at work.

James improved on his car in a traction vehicle, built in 1829, in which, however, he employed the same kind of boiler, which was made up of nearly 200 tubular rings and 400 ft. of 1·9 cm. (¾ in.) water tube enclosed in a space 1 m. 22 cm. by 91·4 cm. by 61 cm. (4 ft. by 3 ft. by 2 ft.). The exhaust from the engine was so hot that it melted the solder of two copper tanks in which the feed water was heated, brazing with hard solder being rendered necessary.

An automobile, resembling in general appearance a four-horse mail-coach, was patented in 1825 by Burstall and Hall, but it failed owing to its boiler, which was placed in the rear, and which consisted of a cast-iron fire-box, whose upper surface formed shallow trays or dishes immediately over the fire-grate. Water was injected into these trays from a feed-water tank, the pressure in which was maintained at 4·2 kg. per cm.^{2} (60 lb. per sq. in.) by pumps which forced air into the upper part. The boiler resembled the modern flash boiler or instantaneous generator, the wrought-iron shell surrounding the cast-iron fire-box, which had a rather long chimney. The boiler fed a grasshopper engine, having two vertical beam cylinders, whose beams were directly connected to cranks at right angles, the main axle being the crank-shaft. The intention was to make the front axle a driving axle also by means of the bevel gearing, there being a universal joint just in front of the water tank to permit of the movement of the front wheels for steering. The exhaust from the engine was passed into a silencer, and its emission therefrom regulated so as to prevent noise. The engines were said to be capable of giving 10 horse-power, but the reported obtainable speed was only from 5·95 km. to 6·9 km. (3·7 to 4·3 miles) per hour, and the whole thing was a failure.

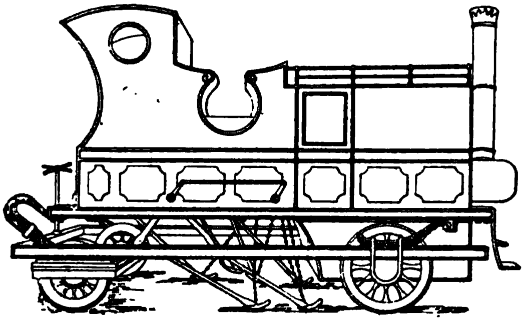


Fig. 2.—David Gordon's Steam Carriage.

Following on the James and Burstall patents, several inventions appeared in Great Britain and in the United States, there being a few road trials in the former.

Sir Goldsworthy Gurney's first attempt at automobile construction was a steam carriage impelled by legs moved backwards and forwards by steam cylinders, but, abandoning such an impracticable vehicle, he devoted himself to traction engines, and in particular automobiles of an advanced type. In a carriage built by Gurney in 1828 the boiler was at the back, as shown in Fig. 3, which is reproduced from the Minutes of Proceedings of the Institution of Civil Engineers (as is also Fig. 4), and consisted of a layer of tubes slightly inclined to the horizontal, these forming the bars of the fire-box, which had a door at the back not shown in the figure. These tubes were bent over as shown in Fig. 3, being shaped like the letter < on its side, the ends running into two large horizontal boilers connected by two vertical tubes. From the top boiler the steam goes into a wrought-iron steam-chest, which acts as a separator for the primed water, which returns to the lower boiler, and for the steam which passes out near the top through the pipe to the front, thus crossing the smoke box, where it dries; then it passes to a cock which the driver works by aid of the side lever, finally entering the slide valve box of cylinder.

Gurney used steam at a pressure of from 4·9 kg. to 8·4 kg. per cm.^{2} (70 lb. to 120 lb. per sq. in.), the average pressure in the cylinder being 2·8 kg. per cm.^{2} (40 lb. per sq. in.). The piston drives the back wheel with a connecting rod, and a crank and a wheel by the aid of the eccentric gear works the slide valve. The valve mechanism is worked by a cord, and by a lever the driver controls the entrance of steam into the cylinder, so as to start the car, change its rate of speed, run back or stop. After acting in the cylinder the steam passes to a kind of condenser cooled outside by the water in the tank; the non-condensed steam goes to the funnel and increases the draught. Moreover, the latter was assured by a fan driven by a little steam motor which also drives the feed pump. This pump receives water from the tank where it is heated by the waste steam, and sends it through the smoke-box into the top horizontal boiler. To set the boiler working, a little pump was operated by hand. Steering was obtained by aid of a fifth wheel in front, which, under the action of a lever guided the shafts in the required direction. Sir Charles Dance established a regular service with Gurney cars between Gloucester and Cheltenham, running four journeys daily. It took 45 minutes, or at most an hour, to cover the distance of 14·48 m. (9 miles). These cars travelled a distance of about 6,440 km. (4,000 miles) from 21st February to 22nd June, 1831, the number of passengers being 3,000. On June 23rd the axle of a car broke, and this accident though not serious, was the origin of a severe attack on automobiles.

Although great difficulties were placed in the way of Sir Charles Dance, he persevered in his attempt to popularise automobilism, and in connection with Maudslay and Field he patented a new boiler, which, resembling Gurney's, was of the water-tube type; its tubes were arranged crosswise like a large letter X, and at the bottom of the legs of the X were two horizontal tubes, extending fore and aft the length of the boiler. Smaller tubes started from these horizontal tubes, partly at an angle of about 45°, and so disposed as to pass each other at the centre of the X, beyond which they were completed by means of an elbow and junction pieces. Within these, says Beaumont in the Cantor Lectures already alluded to, the water was separated from the steam, this latter passing away by pipes on the top of the junction pieces, which were connected by horizontal cross tubes, from which the dry steam was taken. A carriage fitted with this boiler is recorded by Sir Frederick Bramwell to have worked extremely well; it travelled from London to Reading, a distance of about 72·4 km. (45 miles) from Hyde Park Corner, in 3¼ hours, towing a full omnibus all the way. The new boiler was considered to have a greater efficiency than the previous ones made by Gurney.

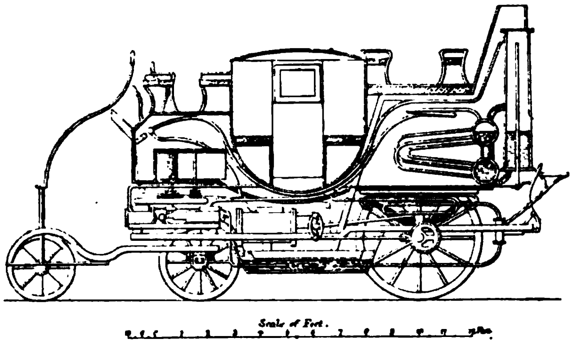


Fig. 3 —GURNEY'S STEAM COACH.

About the autumn of 1831, William Alltoft Summers and Nathaniel Ogle made two steam carriages, one of which frequently attained the speed of 48·3 km. (30 miles) an hour, according to Summers. This vehicle was a treble-bodied phaeton, having only three wheels, and when water and fuel were on board weighing only 3 tons, it being capable of carrying from 16 to 18 passengers. The driving wheels had a diameter of 1 m. 68 cm. (5 ft. 6 in.), former wheels 15·2 cm. (6 in.) larger in diameter having given way at the felloe end of the spokes. The boiler, 1 m. 12 cm. (44 in.) high without case, and 71 cm. by 91·4 cm. (28 in. by 36 in.) on plan, was a vertical water-tube boiler having six rows of tubes, and there were internal smoke tubes, 91·4 cm. (3 ft.) long. The grate surface was 55 m.^{2} (6 sq. ft.), and the total heating surface was nearly 23·2 m.^{2} (250 sq. ft.). The (reputed) 20 h.-p. engine used with this boiler had 19 cm. (7½ in.) cylinders and a stroke of 45·7 cm. (18 in.), and was coupled direct to the crank driving axle.

The good work of Walter Hancock (1799–1852), one of the most important personages in the history of the steam automobile will now be investigated.

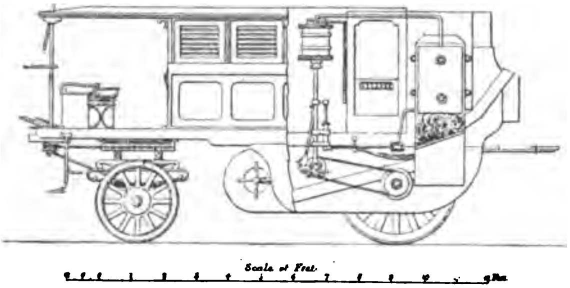


Fig. 4.—Hancock's Steam Omnibus.

After having built various types of steam carriage, the first of which was a steam tricycle in which the single wheel in front was driven by two oscillating cylinders, Hancock invented in 1829–1833 the omnibus shown by Fig. 4, in which the most characteristic feature is the high-pressure boiler, which was economic and efficient. The boiler is seen at the back of Fig. 4, a section being shown by Fig. 5. The water was contained in vertical compartments A, separated by partitions B, in which were grooves for the circulation of the hot gases. These partitions were plates of soft iron, or preferably copper, in which hemispheres had been hammered on a suitable die, the plate being folded down the centre on itself and riveted along the edges, so that the concave sides of the hemispheres came one opposite another. The embossed sheet was bent to a thin bag form, having the hemispheres or bosses on each of its outer sides to rest against those of the next plates, so forming fire tubes. Big central holes in the plates were furnished with bronze or copper rings, which together formed the big horizontal tubes perforated with holes (see Fig. 5), the top one containing steam and the lower one water. Rods L, with screwed ends, carry nuts to tighten the rings one against the other, and with rods E hold together all the parts, forming a water-tight box inside the plates shown at C. The

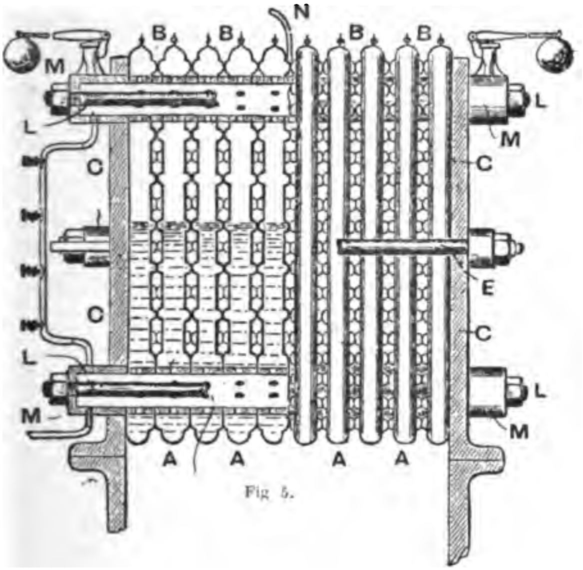


Fig 5.

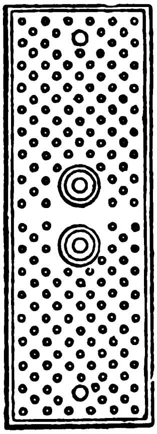


Fig. 6.

Fig. 5.—Hancock's Boiler. Fig. 6.—Plate of Hancock's Boiler.

feed water entered the boiler through the pipe shown at M, and its level was shown in the vertical tube furnished with gauge cocks; the steam made its exit through the pipe N. All the parts were enclosed in a box shown in Fig. 4, the box itself being inside an outer shut casing containing the grate, which was automatically fed with coke; a current of air was supplied by a fan in the centre of the underpart of the car. The steam worked an engine having two vertical cylinders which drove the feed pump, the fan, and especially a shaft which transmitted motion by chain pulleys to the rear axle. The steam on leaving the cylinders passed to the fire-box, crossed the grate, and escaped invisibly and without noise from the funnel. The wheels, with cast iron hubs, had wood spokes compressed between two metal discs. The outer disc on each driving wheel had cast on it two projections, with which two similar projections came into contact to transmit motion from the motor. This system of contact allowed the two wheels, though made interdependent by the motor parts, to turn about 100° in relation to one another, a sufficient amount for ordinary turns. For sharp turns the motor parts had a special screw device, by which the outside wheel made several turns whilst the other wheel remained motionless. The complication of this system may be contrasted with the modern differential gear, to the greater appreciation of the latter. Hancock built nine cars, six of them having boilers like that just described, which gave very good service. For 20 weeks, in 1836, five of these vehicles formed a regular service between Stratford, Paddington, and Islington, carrying in all 12,761 passengers and running 6,760 km. (4,200 miles). Thus Hancock achieved a practical success, so far as proving the possibility of steam locomotion on common roads, though it is doubtful whether his experience pointed to the possibility, at that date, of any commercial success. His work was greatly in advance of anything preceding it or immediately succeeding it; but still, the best of his coaches provided but poor comfort for passengers, who, though seated in front of the motor, must have been subject to considerable vibration, resulting from the employment of powerful and unbalanced engines, and the transmission of their power by rough chain gear. Hancock accomplished much, but left much more to be accomplished.

Although Hancock's work overshadows that of his contemporaries, some mention must be made of two or three other inventors, the products of whose ingenuity appeared sometime in or near the fourth decade of the 19th century. Macerone and Squire, in the year 1834-1835, made and operated a steam coach fitted with a vertical water-tube boiler containing about 80 vertical tubes, connected top and bottom by small stay tubes. There was a central steam receiver, and the engine worked at a maximum steam pressure of 8·5 kg. per cm.^{2} (150 lb. per sq. in.). Such a steam pressure was far in advance of practice which obtained many years after, and, indeed, big pressures are only now becoming popular. The engines used had pistons of 19 cm. (7·5 in.) diameter, and 40 cm. (15·75 in.) stroke; the cylinders were fixed on the perch-pole underframe, and coupling was direct to a crank-shaft which formed the driving axle. As in previous cases, the use of a crank axle caused much trouble, which subsequently was avoided by the arrangement devised by Hancock as described on p. 12. The almost self-feeding furnace was fed with the coke fuel from a hopper, the forced draught being supplied by a fan pulley, driven from one of the road wheels. The average hourly speed obtained is reported to have been 22·5 km. (14 miles), and the total distance run by the coach was 2,735 km. (1,700 miles). Beaumont characterises as "absolutely untrue" the widely published statement that this distance was covered without any noteworthy repair.

Joseph Gibbs patented, in 1830, a boiler which he, in association with Chaplin, afterwards employed on a steam tractor. The boiler had a nearly rectangular fire-box, delivering into two spiral tubes down which combustion products passed and escaped about 61 cm. (2 ft.) from the ground. The fire-box was water-jacketed partly, and the fire was forced by a fan blast. Friction clutch bands, like eccentric straps, were used for gripping either or both of the naves of the driving wheels, so that either could be loosened when turning corners.

Mention will now be made of Dr. Church, who applied many ingenious ideas in building automobiles, J. Scott Russell, and many others, who ran public cars at speeds approaching 24 km. (15 miles) an hour, and it would be unfair not to recognise in their vehicles the germ of many devices now in current use.

Dr. Church, of Birmingham, constructed elaborate but comfortable steam coaches between 1832 and 1835, and in them were introduced some novelties in connection with spring wheels and water-tube boilers. Church's boilers were of two kinds (1), fire-box and water tube, and (2) smoke-tube boilers. Beaumont considers the water space to be too confined, and the firing to be more difficult than with modern boilers, though with slight modifications Church's originals might do excellent service even now.

Somewhere about 1840 J. Scott Russell built six steam coaches, and these were operated, both in England and Scotland, from that date until as late as 1857.

Gear-driven front steering wheels and gear-driven back wheels were employed in a coach made in 1840 by F. Hills, of Deptford, in which the underframe resembled that used in railway practice with respect to the spring suspension and carrying the driving axle between the pairs of horn plates. Hills was the first in connection with automobile practice to allow the wheels to rotate differentially on turning corners. One of his coaches ran from London to Hastings —a distance of 206 km. (128 miles)—in one day, the load probably being nine passengers, a driver, conductor, and stoker. This coach had two engines with 25·4 cm. (10 in.) cylinders and 45·7 cm. (18 in.) stroke, and they were coupled direct to the main crank axle. The two 1 m. 98 cm. (6 ft. 6 in.) driving wheels were inside the main bearings, and loose upon the crank, and either or both could be driven by the crank through clutches operated by the driver. For turning ordinary road curves, the clutch projections engaging with the wheels permitted nearly half a revolution of freedom; and for turning sharp curves, one of the clutches had to be thrown out. The boiler on Hill's coach was tubular, and weighed 1,420 kg. (28 cwt.), not including the weight of water carried with it. The water tanks were of 545 l. (120 gal.) capacity, and, on a journey, at every 12·8 km. (8 miles) a supply of from 363 l. to 454 l. (80 to 100 gal.) of water had to be taken on board. The steam pressure used was from 4·2 kg. to 4·9 kg. per cm.^{2} (60 lb. to 70 lb. per sq. in.), and the speed was as much as 40·2 km. or 48·3 km. (25 or 30 miles) an hour. Hill invented and patented a two-speed gear of the lathe back gear type, and a differential gear, but does not appear to have used either.

William Worby's agricultural self-moving machine, though strictly speaking hardly an automobile, may here be mentioned as illustrating the progress made in the application of steam in the early decades of the 19th century. In 1842 Worby exhibited this self-mover at the Royal Agricultural Society's Bristol show, and its purpose was to have its own threshing machine. Apparently this was the first road engine driven by pitch chain, and according to Beaumont the first driven by a rotary engine; p. 16, however, states that Pecqueur, in 1828, constructed a steam wagon employing a rotary engine.

As may be seen by a comparison of dates, few of the above vehicles were made prior to Hancock's, though most of them after, but in nearly all cases were they abandoned, showing fairly conclusively that the only really practicable vehicle was Hancock's. Most of them were incapable of continuous service, owing either to the great discomfort their crude construction and more or less frequent breakdowns caused passengers, or to the great expense of running them and keeping them in repair.

The new style of locomotion seemed to have acquired abiding rights in England, when certain regrettable accidents were a signal for a regular attack. The campaign was conducted by the railway companies and carrying companies, who regarded automobiles as a dangerous rival; and in 1836 the Locomotive Act was passed by Parliament.

Some persons attach but little importance to the part played by the malignity of the railway companies in the fall of the steam road carriage from popular favour, and rather attribute the failure to defective mechanism, the frequency and gravity of damage, expenses for repairs, and the high cost of running. Be that as it may, it is a fact that automobile owners in England had to pay extortionate, and, indeed, prohibitive tolls, on the turnpike roads; for instance, between Prescot and Liverpool the coach toll was 5s., but for steam carriages it was £2 8s.; on the Bathgate road the tolls respectively were 5s. and £1 7s. 1d.; and on the road between Ashburnham and Totnes the 3s. toll for coaches rose to £2 for steam carriages. Heavy taxes were levied on the tariffs for automobile transports. The wheels had to have an exaggerated width of tyre or were heavily taxed. On roads a man had to walk in front of the car waving a red flag, a restriction tantamount to prohibition. In fact, until August 15th, 1896, the date when the Locomotive Act was repealed, there were only some traction engines and a very few light motor cars running in England.

The useful history of the development of the automobile in England from the year 1840 to about 1895 can be summed up very briefly, as there is but little of importance to chronicle, the restrictions mentioned in the last paragraph effectually hindering development in any direction. Some three-wheel road steamers made their appearance, notable among these being those made for the Earl of Caithness, and for the Marquis of Stafford, by Ricketts of Stafford. One of these vehicles weighed 1·5 tons, carried three or four persons and a stoker, and had a locomotive form of boiler, and a horizontal engine; on one end of the engine crank-shaft was a pitch chain pinion driving the 91 cm. (3 ft.) driving wheels at a ratio of 1 to 2½. The steamer made by Ricketts for the Earl of Caithness was very similar, but it weighed 2·5 tons, and the main axle was driven by gearing instead of chain. The Carrett and Marshall road steamer (1861), known as the "Fly-by-Night," also had three wheels, and whilst it was able to carry eight or nine persons, including the stoker, its weight was more than 6 tons. R. W. Thompson's invention in 1845 of the pneumatic tyre, having a leather outer cover and a canvas-rubber inner tube deserves recording. Beaumont's papers (1897) give the names of persons who constructed road steamers during the period above mentioned, but none of those vehicles is important, though that of H. P. Holt (1866–67) had some claim to originality; in it the two driving wheels were chain-driven by two little double-cylinder engines running independently, in the manner suggested by James more than forty years previously. The boiler was of the fire-engine type and had Field tubes; the exhaust from the engines passed into a cast-iron box forming a baffle plate at the bottom of the uptake; the superheated exhaust, almost noiseless and generally invisible, issued from five jets. A steam brougham, constructed by Mackenzie, employed a similar device. Practically the only other development in England prior to 1890 that is worth recording here is that of Perkins, whose one-wheeled steam-horse or tractor (1870) had a Thompson pneumatic tyre, with a steel chain-link tyre outside it. The boiler was carried immediately over the driving wheel, and had a water tank on one side of it, and on the other a small high-speed engine connected by bevelled gearing to the road wheel. The average steam pressure used in the engine was 17·5 kg. per cm.^{2} (250 lb. per sq. in.) during experiments made with a light van weighing 2,900 kg. (57 cwt.) with load. The speed was only three miles an hour, and the steam horse could haul only about double its own weight.

It was in France that the automobile idea was destined to revive. It had slumbered during the 100 years which followed the invention of the Cugnot trolley. In fact, nothing worthy of note is to be found during this long period of time except the steam wagon constructed in 1828 by Pecqueur, chief of the workshops of the Conservatoire des Arts et Métiers, and the running of some traction engines. In the Pecqueur wagon the two driving wheels were keyed on the two parts of the rear axle, connected by the inventor's planet gearing, the origin of the present differential or balance gear. The fore-carriage alone was fitted with springs; it carried the boiler and the rotary engine, the movement of which was transmitted to the axle by a chain passing round a pulley. This fore-carriage moved round a pivot by means of a toothed sector gearing with the lower pinion of the vertical shaft of the steering bar. The axle arms of these wheels were pivoted vertically in forks at the ends of the axle; but these arms were connected, so as to remain parallel. Thus, in the Pecqueur wagon, is found the germ of all the mechanism of the modern automobile, and had all subsequent inventors been acquainted with it, many useless endeavours might have been spared.

In 1835 Dietz constructed an ordinary road traction engine. He was the first to discover the utility of indiarubber tyres. Between the wooden felloe and the iron tyre of each wheel was placed tarred felt, cork, and, finally, indiarubber, secured by cheeks bolted on to the felloe. In 1856 Lotz ran a steam passenger carriage, steered by means of a single front wheel. In 1866 Séguier suggested the idea of driving each wheel by a separate motor, and it was applied, in 1870, by Michau.

A grand awakening followed after this long period of slumber. As early as 1862 Lenoir, followed in 1870 by Ch. Ravel, had endeavoured to employ gas motors for propelling vehicles, and in 1873 Amédée Bollée built *L'Obéissante*, a steam car capable of carrying twelve passengers; it had a Field boiler and two cylinders, inclined at an angle of 40°, acting upon the rear axle, and could be steered easily, as the fore-carriage was constructed with two pivots, in accordance with Ackermann's invention. A more improved car left the workshops of Bollée, at Mans, in 1880. This was *La Nouvelle*, the omnibus which, 15 years later, was to cover, in 90 hrs. 3 mins. 1,200 km. (745 miles) in the famous race from Paris to Bordeaux and back (*see* p. 765).

Serpollet applied his new boiler to a tricycle in 1888, and then to a car, with four seats, which was run in Paris. In the same year Count Albert de Dion, Georges Bouton, and Trépardoux constructed a steam tricycle with its driving wheel behind, and in 1889 they exhibited a steam car; then in 1893 they built a traction engine capable of hauling any kind of vehicle at a speed of 45 km. (24 miles) per hour. Shortly afterwards Le Blant's traction engine appeared, and also Scotte's road train; and thus it appears that by this time steam had acquired a definite place in automobile locomotion.

With regard to petrol motors, which were to make good for lost time in a brilliant manner, Lenoir had, as early as 1862, employed a gas motor fed with carburetted air instead of gas to drive a car which ran in three hours from Paris to Joinville-le-Pont; but the relatively great weight of the motor, and small number of piston strokes (about 100 per minute) resulted in very low speed, and hindered success. Mention was also made, without stating that it ever ran, of a petrol car built by Siegfried Markus, of Vienna, in 1877. However, it may be said that petrol spirit never really worked a car until the end of 1883, by which time Delamare-Deboutteville had constructed what is thought to be the first gas tricycle which actually ran on the public road. The tricycle motor received illuminating (coal) gas compressed at 10 kg. per cm.^{2} (142 lb. per sq. in.) in two metal vessels. Working with Malandin, the inventor just named made a carburetter, which first was applied to their fixed motor, and then to that of a petrol car. Their patent specification of February 12th, 1884, appears to give them the priority often ascribed to Daimler or Benz, whose petrol cars followed in 1886, and had an equally brilliant career. However, the general employment of petrol spirit is due to two Frenchmen—the late Levassor and his companion Panhard, who, in 1889, exhibited in Paris a tramcar having a Daimler motor. In 1891 a Peugeot car with Daimler motor ran from Paris to Brest. Whilst it is impossible here to trace the progress made in petrol motors, element by element, it is sufficient to say that such a motor is to-day a highly successful machine, and its advancing stages are marked by the trials of the *Petit Journal* (1894), organised through the initiative of Pierre Giffard, the Paris-Bordeaux races (1895), Paris-Marseilles (1896), Paris-Dieppe (1897), Paris-Amsterdam (1898), tour through France (1899), Paris-Bordeaux (1899 and 1901), Richmond trials (1899), the great Continental races of 1901, 1902, and 1903, and the valuable reliability trials organised through successive years by the Automobile Club of Great Britain and Ireland.

Electricity as motive power for automobiles was suggested in a practical way a little before petrol. Whilst Rafford was making the first experiments with accumulators for tramways, G. Trouvé constructed, in 1881, a tricycle driven by one of his small motors, fed by six Planté cells. In 1882 Ayrton tried a tricycle; in 1887 Volk a voiturette with three wheels and two seats; in 1888 Immisch a dogcart with four wheels; in 1893 appeared Pouchain's phaeton, and in 1894 that of Jeantaud. The cab trials of 1898, 1899, and 1902 demonstrated the possibility of using electric cars for public service in towns and cities, where there is facility for the frequent charging of the batteries.

CHAPTER II.

MOTIVE AGENTS FOR AUTOMOBILES.

IN considering the available forms of motive power for use in automobiles, it may be said that steam, petroleum and its products, and electricity are the only agents in use for the propulsion of road vehicles. The question as to whether they could not be beneficially auxiliated or replaced by others is suggested when running through the long list of the sources of energy employed for various purposes. In the case of compressed air and hot water for tramway traction, Marcel Deprez has given a very clear answer. (Conference of the Automobile Club of France, *Génie Civil,* 20th February, 1897, and following.) It seems that, all else equal, preference should be given, as regards automobiles, to the agent possessing the maximum specific power, that is to say, that agent which, for a unit of weight, will produce the greatest number of kilogram-metres or foot-pounds. Of course, the weight of the requisite machinery for converting the agent to power, together with that of all accessory appliances, must be taken into account. The facilities for employing this specific power also must be considered. These two characteristic factors of aptitude for road traction in the various agents of energy will now be studied, beginning with those in current use.

It is in burning coal in a fire-box, utilising the heat produced to vaporise the boiler-water under pressure, and making this steam act on the piston in an engine cylinder, that the potential energy of coal is realised; or, to speak more plainly, it is in this way that the quantity of heat represented by the coal is transformed into work: 1 kg. (2·2 lb.) of coal or coke represents from 8,000 to 9,000 calories, and one calory (3·96 British heat units) is equivalent to 425 kgm. (3,074 ft.-lb.). Theoretically 1 kg. of coal represents at least 3,400,000 kgm. (11,152,000 ft.-lb. per lb.). Practical utilisation of this energy is easy; the steam locomotive, that marvellous engine, is a manifest proof of this. Hauling a load of

150 t. (147 tons) at a speed of, say, 96·5 km. (60 miles) an hour, it vaporises 8 kg. of water per kg. (of course, 8 lb. per 1 lb.) of fuel, giving at the wheel tyres 25,000 available kgm. per kg. of steam (82,200 ft.-lb. per lb.), that is, 200,000 kgm. per kg. of coal (657,000 ft.-lb. per lb.) burnt in the fire-box. Milandré and Bouquet propose the employment of ether instead of water on account of the economic results obtained with the Susine fixed motor. Ether may have a greater specific power, but it is not likely that such an expensive and dangerous agent will drive water from the field.

Passing on to petroleum and the products of its distillation, it is admitted that 1 kg. (2·2 lb.) of the heavy oil, petroleum, represents at least 10,000 calories (39,660 British heat units); and the calorific power of petrol spirit is hardly less than that of the petroleum. Aimé Witz ascribes a calorific power of 11,400 calories (45,210 British heat units) to a good petrol spirit (density 0·700), and about the same for petroleum (density 0·850). (For the distinction between "petroleum" and "petrol spirit," *see* p. 108.) To utilise this potential energy a carburetted mixture is formed with the air and with the hydrocarbon (oil or spirit), and this mixture then is exploded in the cylinder of a motor. The effective work given by 1 kg. (2·2 lb.) of petroleum at the wheel tyres is estimated by Deprez at 750,000 kgm. (5,425,000 ft.-lb.), but a much smaller estimate may be accepted; that quoted by Deprez represents a consumption of 0·5 l. (·88 pt.) of petroleum per horse-power hour. Now the very exact tests to which the cars which ran in the *Times Herald* trials at Chicago (*see* p. 766) were subjected demonstrated the average consumption to be 2·5 l. (4·4 pt.) of spirit per horse-power hour, measured at the wheel tyre. This consumption corresponds to 150,000 kgm. (1,085,000 ft.-lb.) available at the wheels. No doubt, since the Chicago race, run in 1895, the consumption of oil by traction motors has fallen, but it is still much greater than Deprez's estimate, so that if the power available at the tyres is taken at 250,000 kgm. (1,808,000 ft.-lb.) it will not be far from the truth. Moreover, a very simple calculation leads to this figure: the 750 kgm. (5,400 ft.-lb.), available at the tyres, is equivalent to an efficiency of $\frac{750.000}{4,250,000}$ equals 17 per cent.; 4,250,000 kgm. is taken as the theoretical power given by 1 kg. (13,910,000 ft.-lb. per 1 lb.) of petroleum. Now, very good fixed petroleum motors, especially Priestman motors, give an efficiency of only 13 per cent. on their pulley shaft, whilst consuming 0·625 l. (1·5 pt.) per horse-power hour. Such a motor, in the construction of which neither weight nor encumbrance has to be considered, is certainly more economic than an automobile motor in which weight and dimensions must be reduced to a minimum. It will be shown later (p. 807) that in an automobile motor not more than 11 per cent. of the total energy on the driving axle, and only 5·5 per cent. at the tyres, can be obtained, owing to losses caused in transmission. The energy available at the wheels, then, is equivalent to 4,250,000 × 0·055 = 233,750 kgm., or, in round figures, 250,000 kgm. for every 1 kg. of petroleum (820,000 ft.-lb. per lb.). The use of a Diesel motor and perhaps of other but particularly economic motors, may make it possible to greatly augment these figures. Practical application of petroleum, although the motor is more complicated than the steam engine, is possible and, of course, daily realised; the application becomes an easier matter when use is made of petrol spirit, which, it is hoped, will soon become as common as the heavy coal tar oils, the calorific power of which rises to 15,000 calories per kg. (27,040 British heat units per lb.), almost double that of coke; 1 kg. of these oils could easily vaporise from 13 kg. to 15 kg. (29 lb. to 33 lb.) of water.

With regard to electricity, the best secondary batteries, commonly called accumulators, or storage batteries, give per kg. from 5,000 to 10,000 kgm. (16,400 to 32,800 ft.-lb. per lb.), says Pisca, whilst Hospitalier's estimate is 7,000 to 8,000 kgm. (22,960 to 26,240 ft.-lb. per lb.); the latter estimate is deemed preferable. The specific power of electricity supplied by accumulators is much less than that of petroleum, the former being scarcely 4 per cent. However, the second condition — namely, facility of utilisation — is so well fulfilled that, as will be shown later, the electric car is quite possible.

The suggested substitutes for the three above agents will now be considered, taking in the first place gas under pressure and compressed air. As regards air, its native density, even under heavy pressure, is very slight, and enables it to accumulate considerable energy; 1 kg. of air compressed at 45 atmospheres is equivalent to not less than 20,765 kgm. (68,110 ft.-lb. per lb.). It must, however, be confined in a receptacle weighing thirteen times more than itself, so that the specific power of this same confined air is not more than 1,608 kgm. (11·600 ft.-lb.). This cannot compare with 4,250,000 theoretic kgm. and 250,000 kgm. effective at the wheels given by 1 kg. of petroleum (13,940,000 ft.-lb. and 1,190,000 ft.-lb. per 1 lb.). As regards practical employment of compressed air, its use on public tramways will be familiar. The air compressed at 45, 60, and even 90 atmospheres, by aid of a special apparatus, which must be prevented from heating, is carried in receptacles on the car. The compressed air does work by its expansion in the motor cylinder, but as this expansion would be followed by cooling and formation of ice in the cylinder and exhaust pipes, the compressed air must be heated before use, by making it bubble through hot water, or by passing through heated pipes. All this certainly complicates the use of compressed air as regards automobiles, but its use is possible for tramcars which, whilst always running along the same road, and periodically returning to the charging stations, are sufficiently big to carry heavy receptacles containing the fluid. Finally, the decrease of traction strain offered by the rails and the number of passengers simultaneously transported make the cost per car-kilometre or per car-mile reasonable, though still relatively great. (With the Mekarski tramways of Paris and Nantes, whose cars each weigh 12 tons and carry 50 passengers, the cost per car-kilometre is 3·3d., that is, 5·3d. per car-mile; in the former figures, the compressed air is represented by 1·9d., repairs of pipes 0·70d., and repairs and lubrication of the car, 0·67d.)

This would not be feasible for an automobile which must find supplies easily and has not space to carry sufficient tanks for a long journey; and consequently, in spite of its real advantages as regards cleanliness, ease of starting and stopping by aid of a valve, and the impossibility of fire, this system of propulsion does not seem to be suitable for automobiles; this fact explains the failure of experiments. W. Mann in 1822, Wright in 1830, and Fordham in 1832, prepared plans for compressed air automobiles which have never been executed. In 1840, two French engineers, Andraud and Tessié du Motay, built the first compressed air car, and on July 9th of the same year it made a trial trip at Chaillot on a railway track; its structure would have enabled it also to run on roads, but there is doubt whether it ever ran on any other occasion than that mentioned. Recently, Hartley of Chicago constructed a tricycle with a reservoir between the two front bearing and steering wheels. This air container drove a two-cylinder motor, which transmitted its motion by means of two chains to the rear driving-wheel. An average speed of 12·8 km. (8 miles) an hour was obtained: but though the Chicago postal authorities endeavoured to substitute it for some of their ordinary cars, it is not thought to have much of a future, even for purely city service. Ravel states, in a French publication, that this system, tried about 1888 on a tramway, showed a loss of 70 per cent. by the transmission gear.

Finally, at the Paris Salon of 1899, the firm of Molas, Lamielle, and Tessier exhibited a heavy goods vehicle; but, though it may be regarded as the medium between the light car, for which the employment of air seems impossible, and the tramcar, for which it is used daily, it is not believed that this application will lead to anything. The vehicle in question, originally constructed for animal traction, was adapted with only the minimum number of alterations actually required for its new use. The air supply is said to be carried in bottles made of a special kind of soft steel, which does not burst, but tears like lead when the pressure is too great to be withstood. Some further particulars should be given of this steel, which so surely obviates the danger of storing gases compressed until they give a pressure of not less than 300 kg. per cm.^{2} (4,270 lb. per sq. in.). Many tramcars in France employed air compressed to only 45 atmospheres, and in any case it is not believed that the pressure in the above case exceeds twice that, whereas Molas, Lamielle, and Tessier make it more than six times. In America, it is said, the air is now compressed to this pressure. A suitable expansion brings the compressed air to the pressure at which it is employed in the cylinders, namely, 60 kg. to 4 kg. per cm.^{2} (854 lb. to 57 lb. per sq. in.), and the precautions taken to prevent the formation of ice are not stated. The motor, composed of four single-acting cylinders, is placed with its adjuncts in the car, under the driver's seat, out of the way of mud and dust; and the makers say that a special system of distribution enables the air to be employed to within the last few cubic centimetres. Normally, the motor makes only 280 revolutions per minute, and from 1 h.p. to 35 h.p. can be obtained. The four pistons directly drive the intermediary shaft carrying the little sprocket wheel, which, by means of chains, impels the driving wheels, these being at the back of the vehicle, and furnished with sprocket pulleys; a stretcher, said to be similar to two guide rollers, keeps the chain links in the pockets intended for their reception. Steering is made possible by means of a pivoted fore-carriage. The constructors give the following figures:—

Weight of car	1,400 kg. ...	3,090 lb.
„ „ motor and adjuncts	450 kg. ...	990 lb.
„ „ compressed air tanks	1,050 kg. ...	2,315 lb.
„ „ car in running order...	2,900 kg. ...	6,500 lb.
„ „ useful load	2,000 kg. ...	4,410 lb.
„ „ useful load compared with total weight of loaded car...	40·8 per cent.	
Speed per hour	10 km. ...	6·2 miles.
Cost of motor car	10,000 fr. ...	£400.
Cost price per ton per kilometre for daily journey of 50 km. (31 miles)	*0·295 fr. ...	2s. 8d.
Cost price per ton per kilometre for daily journey of 100 km. (62 miles)	†0·196 fr. ...	1s. 8d.

* 1s. 7d. per ton per mile.

† 1s. 1d. per ton per mile.

These figures show greater economy than those obtained in the Versailles competition in 1897 (*see* p. 767), but they cannot be compared legitimately until they have been verified by tests made and controlled as carefully as those of the competition. Until then, it will be more economic, it is thought, to burn coal in the boiler of an automobile than in that of a compressor to feed the car.

Almost analogous conclusions apply to the employment of illuminating gas in some Lührig tramcars with an expenditure of 800 l. (28·25 kg.) of gas per car km.; this form of energy was tested in 1883 by Delamare-Deboutteville on a tricycle (*see* p. 18).

With regard to the employment of liquefied gases and carbonic acid, it may be said that the specific power of a liquefied gas is proportional to the amount of work expended to bring it to this state. The method of utilising this work is very similar to that of compressed gases; when the pressure which keeps the gas liquid is removed, the gas returns to its former state, its expansive force working the piston, and the gas absorbing a quantity of heat equivalent to the amount of which it was deprived by the process of liquefaction. As the heat at which the liquid gas is vaporised is always much less than that of water, and also for many other causes, water is much preferable to liquefied gases. Liquefied gases are less inconvenient to carry, power being equal, than compressed gases, but the danger of explosion is greater. In April, 1898, at a meeting of the Franklin Institute, F. Roberts exhibited a 25-h.p. horizontal motor driven by carbonic acid, the total weight of which, bed-plate included, did not exceed 38·5 kg. (84·8 lb.). There were three double-acting cylinders, of 50 mm. (2 in.) diameter, and 50 mm. throw, and the slide valve gear was governed by cams. The force of 25 h.p. corresponded to a pressure of 110 kg. per cm.^{2} (1,564 lb. per sq. in.), and a speed of 2,000 revolutions per minute. The New Power Co. of New York constructed a tramcar motor like a steam engine, although the valve gear and some other details differed; the carbonic acid, accumulated in steel tanks under a pressure of 70 kg. per cm.^{2} (995 lb. per sq. in.), ran directly to the cylinders without any expansion or reducing valve, but with a re-heater. The cylinders are 10 cm. (4 in.) diameter and 15 cm. (6 in.) throw; taking the cost of carbonic acid at New York to be only 0·37 fr. per kg. (3½d. per lb.), that of a horse-power hour in a 24-hour run is only 0·65 fr. (0·6d.). The point to ascertain is whether the working will ever be practicable for an automobile. Motors driven by liquid carbonic acid and hot water have been invented by Francq and Marchena, but they seem very complicated for road traction.

Liquid air, according to F. Richard, will not give the powerful light motor required for automobile locomotion. Employed for producing power and without reckoning the friction of the piston or the great space occupied, a liquid air motor gives only 0·454 h.p. in return for the 73 h.p. expended by the compressor which produced it. There is nothing attractive in an efficiency of 0·6 per cent. It need hardly be said that these figures, like the preceding, must be accepted with reserve. Now is not the time to express any opinion respecting the future of liquid air, which might indeed become a marvellous agent of transport.

With regard to the efficiency of a car propelled by a liquid air motor, Dr. Carl Linde, the well-known German specialist, has stated that the greatest possible efficiency of a liquid air motor is 33⅓ per cent.; that is, a mechanically perfect motor could give as mechanical energy only one-third of the power required to produce the liquid air. But crediting the motor with as high a mechanical efficiency as 50 per cent., only one-sixth of the original energy could be recovered. Then supposing the transmission to have about the same efficiency as the motor, the ultimate efficiency of a liquid air car could not exceed 8·3 per cent., and most probably it would be far below that.

It is stated that George Claude, of Paris, has obtained 1 kg. (2·2 lb.) of liquid air for the expenditure of 1 h.p., and Dr. Linde has stated that this is the utmost limit to be hoped for; but it is impossible to prophesy in this direction.

The modern method of storing liquid air is in glass, not steel, vessels, each containing two bottles, between which is a vacuum; the case is quicksilvered externally to reflect heat. The mouth of each bottle is left open, because with the best of insulations some heat passes through, and this, gasifying the liquid, would create a pressure that no bottle could withstand. Such a pressure would be in the neighbourhood of 800 atmospheres, nearly 844 kg. per cm.^{2} (12,000 lb. per sq. in.). Evaporation is slow, and a film forming on the surface of the liquid is a fair insulation. Dr. Linde says that a charge lasts for two weeks in an open bottle.

With regard to hot-water motors, water heated to 200°, at a pressure of 15 atmospheres, as in the Lam-Francq, accumulates 42 calories per kg. of water (72·7 British heat units per lb.), and thus a tank of water may represent 17,850 kgm. (122·96 ft.-lb.). Deprez states that 10 per cent. of this work can be utilised, that is, 1,785 kgm. per kg. (5,854 ft.-lb. per lb.) transported; this is far less than the energy furnished by petroleum. For practical application of the process the car tanks are filled with hot water, and placed in communication with the cylinders by means of a valve, and part of the water is vaporised, borrowing the requisite heat from the remainder of the water, and the steam thus formed drives the piston. However, when the boiler temperature has fallen to 150° C., and the pressure to five atmospheres, the energy must be renewed. Thus, in one way, hot water is similar to compressed air, being suitable for tramways, but inconvenient for automobiles.

Consequently, although the charging apparatus is less complex than with air (a simple boiler being used instead of a compressor worked by an engine), and although the specific power of hot water is greater than that of compressed air, the employment of the former for automobile locomotion seems to be as futile as that of the latter. It is doubtful, indeed, whether a hot water car has ever been constructed. Recently Hutin and Leblanc patented a system in order the better to use steam in multiple expansion motors having several cylinders (the inventors speak of six), a set of rotary machines, or in turbines. But in the considerations they advance in favour of their idea there does not appear to be anything that can influence the opinion above expressed that hot water is not a desirable motive agent for employment in automobiles.

Since the end of 1892, when Moissan in France and Wilson in America invented a method to manufacture calcium carbide on a large scale (by reducing calcium oxide with carbon in an electric furnace), commercial manufacture of acetylene has become easy by simply bringing the carbide into contact with water. One kg. (2·2 lb.) of carbide gives theoretically 340 l. (12 cub. ft.) and practically 300 l. (10·6 cub. ft.) of acetylene, which is capable of furnishing 3,500 calories (6,310 B.H.U. per lb), which is about one-third of that furnished by petroleum. Since its origin this gas has been employed for lighting, and the question arose early whether the 1,487,500 kgm. per kg. (4,879,000 ft.-lb. per lb.) could not be utilised for motive power. An initial difficulty was immediately encountered; acetylene, an endothermic body—that is, formed with absorption of heat—is a powerful explosive, which is dangerous to handle. Berthelot and Vieille demonstrated that as long as its pressure does not much exceed that of one atmosphere, neither the electric spark nor an ignited point causes explosion. With pressure greater than two atmospheres, an explosion (not combustion, but mere decomposition) may occur in the same circumstances, air not being present. This liability to explosion increases with pressure.

There has been talk of a new carbide designated "carbolite," discovered by H. L. Hartenstein, a chemist of Chicago, for the manufacture of which a works was to be built at Hammond (Indiana). This carbide, obtained by suitable treatment of blast furnace slags, could be made at a cost of 25 fr. (£1) per ton, instead of 500 fr. (£20), which at present is the cost of calcium carbide. Under the action of water 1 kg. of it is said to give 300 l. (1 lb. gives 4·8 cub. ft.) of ethylene, which can be used instead of acetylene. But some persons consider carbolite to be merely a mixture of calcium carbide and aluminium, which in contact with water gives a mixture of methane and acetylene of the same composition as ethylene, but without containing any whatever, and they add that ethylene contains 65 per cent. less carbon than acetylene does, and consequently cannot be a successful competitor.

Carburetted acetylene may yet prove of value in automobile motors. Dr. N. Caro, in a paper read a year ago before the German Acetylene Verein, stated that acetylene gas, when led through petrol, becomes heavily carburetted, 100 l. of the gas taking up 125 g. of petrol and yielding 150 l. of the carburetted gas, of which the calorific value is 50 per cent. more than that of the plain acetylene. In other terms, 3·5 cub. ft. of acetylene takes up 4 oz. of petrol and yields 5·25 cub. ft. The tendency of the petrol vapour to condense and separate from the gas on cooling will complicate the practical application of this powerful motive agent, the difficulties of using plain acetylene already being great.

Liquid acetylene has the maximum explosiveness, and in this respect is comparable to gun-cotton, and its employment in this form, so convenient for automobiles, must therefore be abandoned. At most, all that can be done is to compress the gas in the same way as is done in Paris by the Société des Produits Chemiques, who have sold it in steel receptacles weighing 20 kg. (44 lb.), and holding 250 l. (8·8 cub. ft.), under a pressure of 10 kg. per cm.^{2} (142 lb. per sq. in.). However, it appears that it is better to dissolve it by the Claude and Hess process in acetone, which absorbs as much as 300 times its volume, under a pressure of 12 kg. per cm.^{2} (190 lb. per sq. in.), the bulk of the liquid being increased only by one-half; and it yields 275 volumes of the gas at atmospheric pressure. This solution does not appear to be explosive under the influence of heat when its pressure is not too great. According to the experiments of Berthelot and Vieille, 7 l. (427 cub. in.) of acetone having dissolved 1,170 g. (41 oz. avoirdupois) of acetylene at a pressure of 8 kg. per cm.^{2} (113·7 lb. per sq. in.), did not explode in contact with a red-hot platinum wire. Similar contact in a solution formed at a pressure of 20 kg. per cm.^{2} (284·4 lb. per sq. in.)

caused slight explosions, so it is prudent not to exceed greatly a pressure of 10 kg. per $cm.^2$ (142 lb. per sq. in.). Supposing the question of storage without danger to have been solved, another difficulty presenting itself is the violence of the explosion of the mixture of gaseous acetylene and air in the cylinder of the motor to be worked. Cuinet, with an ordinary four-stroke cycle gas motor, succeeded in obtaining smooth working, free from jerks, by mixing one volume of acetylene with twenty volumes of air. His 6-h.p. motor consumed, at half charge, 302 l. (11 cub. ft.) of acetylene, and at full charge, 175 l. (6 cub. ft.) per effective horse-power hour, this being nearly three times less than the volume of illuminating (coal) gas required for the same motor. With carbide costing 500 fr. (£20) per ton, the horse-power hour would thus cost 0·30 fr. (2·85d.). Experiments made quite recently by Grover, of Leeds, confirm this cost, his estimate being 0·28 fr. (2·66d.). This is expensive, because the motor in question, consuming 516 l. (18·2 cub. ft.) of illuminating (coal) gas at 0·30 fr. per cubic metre (·08d. per cubic foot), would yield the horse-power hour for 0·10 fr. (0·95d.). Ravel tested one of his 2-h.p. two-stroke-cycle motors, and found the power of acetylene to be 2½ times greater than that of coal gas. However, he does not think that the great explosive power of acetylene can give all its useful effect on the pistons of internal combustion motors as built at present; either the acetylene gas must form a large percentage of the explosive mixture, and then give but little useful work, considering the shattering explosion, or the explosive mixture will be weak in acetylene, and then not have sufficient calorific power to raise the pressure of the mixed gas to the point that is necessary if economic work is to be produced. To avoid the difficulty, R. Turr and Ch. Chertemps endeavoured to make use of the considerable increase in temperature due to the very sudden explosion of acetylene to transform a certain quantity of water into steam, and then by expanding this steam to gradually move the piston; but this complicated construction has never been applied. The conclusion, then, that the above remarks lead to is that even if liquid acetylene could be used without danger, it is still doubtful whether it would answer as a motive agent for automobiles.

The substitution of alcohol for petrol spirit in automobile motors would probably decrease the unpleasant odour; and, in the case of France, an imported article would be replaced by a home product, the consumption of which would compensate agriculture for the losses it is expected to suffer in consequence of the smaller demand for horses and fodder—that is, supposing that no method arises for chemically manufacturing alcohol commercially.

Fritsch has already proposed to extract alcohol from ethylene, which is a carburetted gas forming 2 per cent. in volume of blast furnace gas, and which is found also in coke ovens and retorts where coal is distilled. The calorific power of alcohol is only very slightly more than half that of petrol; thus, theoretically, if the work produced by the combustion in the presence of exact proportions of oxygen of 1 kg. (2·2 lb.) of petrol spirit is 6·75 horse-power hours, and by 1 kg. (2·2 lb.) of 90 per cent. alcohol is 3·235 horse-power hours, it follows that a franc's worth (9½d.) of alcohol at 30 francs. per hl. (1s. per gal.) (not including duty) will give 9 horse-power hours, whilst a franc's worth of petrol spirit or of petroleum at 0·45 franc per kg. (2d. per lb.) will give 15 horse-power hours. It might be objected that in practice, perhaps, some very different figures would be obtained, because it is not with the strictly proportional amount of oxygen that combustion is produced, but with a certain proportion of air which contains 23 per cent. of oxygen and 77 per cent. of nitrogen; theoretically, 15·117 kg. are needed per kg. (15·117 lb. per lb.) of petroleum, and only 7·567 per kg. of 90 per cent. alcohol; therefore the great excess of nitrogen absorbs with sheer loss more heat in the combustion of petroleum than in that of alcohol. Besides, it might be easier to obtain complete combustion with alcohol than with petroleum. To elucidate this question, Max Ringelmann was commissioned by the Agricultural Society of Meaux to make experiments, which he made with petrol spirit and impure alcohol (methylated spirit), which were analysed by A. Müntz with the results given in the first table on p. 31.

The first experiments were made with a Brouhot four-stroke-cycle horizontal motor of from 2 horse power to 3 horse power, having electrical ignition, and with a Benz four-stroke cycle tube ignition vertical motor of from 3 to 4 horse power. The results of Ringelmann's experiments are given in the second of the tables that appear in the next page:—

PROPERTIES OF PETROL SPIRIT AND METHYLATED SPIRIT.

Properties.	Petrol Spirit.	Methylated Spirit.
Carbon	84·3 per cent.	41·5 per cent.
Hydrogen	15·7 per cent.	13·0 per cent.
Oxygen...	—	45·5 per cent.
Density at 15° C.	·708	·834
Boiling point	88° C.	78·5° C.
Calories per kg.	* 11,359·65	† 6,521·75
Weight evaporated per hour per dm.^{2} (15·5 sq. in.) of surface :—		
1. In experiment room; 18° C. ...	9·37 g. (0·33 oz.)	3·47 g. (0·12 oz.)
2. Outside in the sun; 25° C. ...	47·21 g. (1·66 oz.)	27·08 g. (0·95 oz.)

* 1,302 British heat units per lb. † 752 British heat units per lb.

MOTOR CONSUMPTION OF PETROL SPIRIT AND METHYLATED SPIRIT.

	Consumption per Hour.		Relation of Consumptions.	
	Petrol Spirit.	Methylated Spirit.	Petrol Spirit.	Methylated Spirit.
Horizontal Motor—				
Empty	1·040 kg. (2·293 lb.)	2·267 kg. (4·998 lb.)	1	2·05
Per h.p. Half Charge	·950 kg. (2·094 lb.)	1·767 kg. (3·896 lb.)	1	1·86
Per h.p. Full Charge	·892 kg. (1·966 lb.)	1·396 kg. (3·078 lb.)	1	1·56
Vertical Motor—				
Empty	·328 kg. (·723 lb.)	·771 kg. (1·700 lb.)	1	2·35
Per h.p. Half Charge	·619 kg. (1·365 lb.)	1·097 kg. (2·418 lb.)	1	1·66
Per h.p. Full Charge	·407 kg. (·897 lb.)	·763 kg. (1·682 lb.)	1	1·87

Thus to obtain the same useful work, an average of 1·89 times more alcohol (methylated spirit) was consumed than petrol spirit. Ringelmann calculated the consumption and cost as follows:—

MOTOR CONSUMPTIONS (RINGELMANN).

	Petrol Spirit.	Methylated Spirit.	Petroleum.
Consumption per h.-p. hour in weight	0·400 kg. (0·88 lb.)	0·756 kg. (1·66 lb.)	0·438 kg. (0·96 lb.)
Consumption per h.-p. hour in volume	0·565 l. (0·99 pt.)	0·906 l. (1·6 pt.)	0·532 l. (0·94 pt.)
Relation of consumption in volume	105·28	169·2	100
Cost of litre (outside Paris)	0·50 fr. (4·75d.)	1·0 fr. (9·5d.)	0·30 fr. (2·85d.)
Cost of horse-power hour ...	0·28 fr. (2·66d.)	0·90 fr. (8·55d.)	0·16 fr. (1·52d.)

The figures in the petroleum column are those obtained at the International Competition at Meaux, in 1894.

Thus the relation of the prices of these agents requisite to obtain the same power is:—

Petroleum	1
Petrol Spirit	1·75
Methylated Spirit	5·625

Ringelmann concludes that methylated spirit should be sold at 17·70 fr. per hl. (7·65d. per gal.) to be equivalent from the economic point of view to petroleum worth 30 fr. per hl. (13d. per gal.), and that consequently employment of alcohol in automobile motors is out of the question. But this is not all, for owing to the small amount of vapour emitted by alcohol at a temperature of 15° to 20° C., he had to have recourse to devices to make the motor work. Ringelmann made the Brouhot motor run for about 15 minutes with petrol spirit, and when the average temperature of the discharged gases got as high as 70° C. he began to feed the motor with alcohol, taking care, however, to modify at the same time the composition (as regards the proportion of air) of the explosive mixture in order to obtain complete combustion (because the alcohol in a cylinder charge is as 2·06 to 1 compared with petrol spirit in a charge). For the Benz motor he had a carburetter which by aid of a gas stove was kept at a temperature of from 42° to 47° C., found by trial to be the most favourable for working the engine, and this carburetter was a constant danger of fire. It will be noticed that Ringelmann compares alcohol (methylated spirit) with petroleum, which latter, however, is employed only exceptionally for automobiles, only a distillation of petroleum, here known as petrol spirit, being in current use, and, as the admitted cost of this is 40 fr. per hl. (17·3d. per gal.) instead of 30 fr. (13d. per gal.), it will be found that alcohol at 23·60 fr. per hl. (10·2d. per gal.) instead of 17·70 fr. (7·65d. per gal.) can be used as cheaply as the petroleum spirit. Ringelmann estimated alcohol at 100 fr. (£4) per hl. (22 gal.) at a time when the duty on the hectolitre of methylated spirit in France was 37·50 fr. (29s. 8¼d.), but a recent law has reduced it to 3 fr. (2s. 4½d.), so that the price may be reckoned as 67·50 fr. the hl. (2s. 5d. per gal.). Moreover, it is hoped that the cost of denaturing alcohol, now 7 fr. per hl. (3d. per gal.), will be decreased; in Germany it is considerably less. Thus the cost of methylated spirit would hardly exceed 60 fr. per hl. (2s. 2d. per gal.). The difference between this price and that which would make alcohol an economical agent, accepting the consumptions as given by Ringelmann, still remains noticeable, but there is a very considerable decrease. Moreover, Ringelmann experimented with motors which were not built to use alcohol, and with which it could only be employed by methods not acceptable in daily practice; and it may be suggested that adaptation of a special carburetter and motor would be the means of removing danger and increasing efficiency. The experiments of Petréano tend to prove this. Employing an Otto gas motor, 1884 type, giving 5 h.p. at 180 revolutions, but furnished with a special carburetter (*see* p. 112) he obtained one indicated horse-power hour for every 0·540 kg. (1·19 lb.) of alcohol used. With a density of 0·815 that gives 0·822 1. (1·55 pt.). The firm of Körting, Hanover, appears to have obtained even better results. In March, 1897, experiments were made with a motor of the benzine type specially constructed for the purpose, and it gave one indicated horse-power per hour, with an average consumption of 0·49 l. (0·16 pt.) of alcohol at 93° C. and 0·815 specific gravity, this corresponding to 0·612 l. (1 pt.) of alcohol per effective horse-power hour. Consumption would hardly be greater than that calculated by Ringelmann for petrol (0·565 l., or ·99 pt.). If these figures are confirmed, the employment of alcohol for motive power now is economical in Germany, where alcohol costs from 20 fr. to 30 fr. per hl. (from 8·6d. to 13d. per gal.).

One of the most important series of experiments to show the comparative value of alcohol as a motive agent was carried out in the Technical High School of Berlin, and from E. Neuberg's record of this in the *Automotor Journal* the following particulars are taken. A 4-h.p. motor was coupled direct to a dynamo, the mechanical energy generated being converted to electrical; the dynamo was a convenient means of varying and testing the horse-power of the motor, and it was carefully tested so as to make certain of its efficiency at different loads, and thereby enable the efficiency of the alcohol motor to be estimated under different conditions. The results of using alcohol are summarised in Nos. 1 to 8 in the following table, of varying the constitution of the fuel by Nos. 9 to 18, and of manipulating the governor, not employed previously, in Nos. 19 and 20:—

No.	Percentage composition of the fuel.			Mean diagram pressure.	Temperature of the exhaust gases in degrees centigrade.	Indicated horse-power in i.h.p.	Effective horse-power in e.h.p.	Price per i.h.p. in pfennigs. ‡	Price per e.h.p. in pfennigs.	Thermal efficiency, %.	Mechanical efficiency, %.	Total efficiency, %.	Converted into work, %.	Lost in cooling water, %.	Carried off in the exhaust gases, %.	Due to combustion to C.O.	Remainder in %.
	Alcohol.	Water.	Benzol and Benzine.														
1	92·50	7·50	—	2·97	349	2·90	1·462	13·10	25·92	17·73	50·5	8·98	17·73	35·75	18·81	1·108	26·602
2	92·50	7·50	—	3·22	370	3·12	1·620	12·27	23·53	18·95	51·9	9·87	18·95	32·70	20·72	0	27·63
3	92·50	7·50	—	3·88	345	3·56	2·646	11·08	14·91	21·00	74·3	15·63	21·00	33·49	18·10	0	27·41
4	92·50	7·50	—	3·86	356	3·79	2·960	11·08	14·13	21·00	78·1	16·42	21·00	36·47	21·81	1·012	29·808
5	92·50	7·50	—	5·68	323	4·28	3·566	11·21	13·39	20·85	83·2	17·35	20·85	38·84	16·76	1·388	22·162
6	92·50	7·50	—	4·85	338	4·40	3·788	10·26	11·89	22·70	86·2	19·55	22·70	34·10	15·51	1·069	26·621
7	92·50	7·50	—	5·74	308	4·72	4·278	10·15	11·15	22·90	90·9	20·80	22·90	33·67	10·45	0·912	32·068
8	92·50	7·50	—	5·82	324·99	5·05	4·076	10·05	12·45	23·10	80·6	18·65	23·10	44·15	15·01	1·117	16·623
9	84·075	6·825	9·1*	5·22	341	4·82	4·047	10·08	12·00	21·85	84·4	18·34	21·85	40·14	13·36	0	24·65
10	77·1	6·25	16·65*	5·38	337·5	4·68	4·037	9·18	10·62	22·90	86·1	19·72	22·90	39·90	12·07	0·0306	25·1094
11	84·075	6·825	9·1†	5·38	321·5	4·43	3·606	9·12	11·12	26·17	81·3	21·24	26·17	43·33	16·08	1·090	13·330
12	77·1	6·25	16·65†	5·66	339·5	4·99	4·006	11·15	13·72	21·79	80·2	17·72	21·79	43·41	12·68	0	22·12
13	67·50	32·50	—	2·72	346·5	2·38	1·265	18·85	34·50	12·35	53·2	6·75	12·35	26·02	11·20	1·145	49·285
14	78·66	21·34	—	3·49	356	3·50	2·274	12·10	18·42	19·39	65·0	12·60	19·39	33·07	16·83	0	30·71
15	87·188	12·812	—	4·81	338	4·44	3·564	10·03	12·80	22·60	80·4	18·17	22·60	36·17	18·77	0·0351	22·4249
16	77·802	22·198	—	5·32	324	4·62	3·414	10·03	13·95	22·49	73·9	16·67	22·49	32·79	17·80	0	26·92
17	79·344	20·656	—	5·78	346	5·23	4·263	10·01	12·48	22·98	81·3	18·64	22·98	38·19	13·97	1·095	23·765
18	60·57	39·43	—	6·54	321	5·38	3·146	9·25	15·76	25·19	58·5	14·74	25·19	26·67	9·35	0	32·79
19	92·50	7·50	—	5·34	308	4·94	3·840	9·51	12·40	24·56	78·1	18·74	24·56	35·10	10·5	0·292	29·548
20	92·50	7·50	—	3·255	321	3·72	1·718	11·12	24·17	20·93	46·2	9·67	20·93	31·23	15·15	0·331	32·359

* Benzole. † Benzine. ‡ 8 pfennigs are equal to one penny.

The mean values for the whole series of experiments can be given as functions of the load as follows:—Thermal efficiency, 21·215 per cent.; mechanical efficiency, 71·1 per cent.; total efficiency, 16·325 per cent.; costs of indicated horse-power and electrical horse-power, 1·39d. and 1·918d. respectively. The exhaust gases showed the presence of acetylene, aldehyde, and acetic acid. On light load there was combustion within the exhaust pipe. Rectification of alcohol for motive purposes is not necessary. The alcohol motor works thermodynamically as economically as any other motor, but according to these experiments it is 45 per cent. dearer than the gas engine, 48 per cent. dearer than the heavy oil motor, 6 per cent. dearer than the benzine motor, 53·5 per cent. dearer than the acetylene motor, and 31·5 per cent. dearer than the electric motor. This is not very satisfactory for the stationary alcohol motor. The cost per horse-power hour is compared with other small industrial motors as follows, the cost of cooling water not being reckoned:—

Kind of Engine.	Per H.P. Hour					
	Depreciation.	Interest.	Attendance.	Oil.	Fuel.	Total.
Gas motor	3·34	1·335	1·04	0·9	8·53	15·145
Petroleum motor	3·34	1·335	1·04	0·9	8·25	14·865
Alcohol motor	3·34	1·335	1·04	0·9	15·35	21·965
Benzine motor	3·34	1·335	1·04	0·9	14·2	20·815
Acetylene motor	4·03	1·61	4·16	0·9	14·2	33·70
Electric motor	1·39	0·556	—	0·2	14·6	16·746

The attempts to use benzine as fuel were unsuccessful, owing to pre-ignitions giving such violent explosions as to knock off the indicating lever over the top of the revolving cylinder, the explosion pressure being more than 40 atmospheres. With benzine, compression cannot be carried above 5 atmospheres without the danger of pre-ignition.

The comparative consumption of petrol and alcohol is of some moment in France, if not in Great Britain. The average results of the French Circuit du Nord, held in May, 1902 (recorded on p. 787), go to prove that the consumption of alcohol is 50 per cent. more than that of petrol spirit under equal conditions. This is 20 per cent. higher than it should be if alcohol is to hold its own against petrol in France. Data on alcohol consumption are given in Chapter XXII.

The French alcohol experiments carried out in such a thorough and exhaustive manner were designed to have the effect of encouraging a native agricultural industry, and that may have been the only cause. But with the progress of the alcohol motor has come a revival of the attempts to produce alcohol synthetically, and already the alcohol produced chemically from calcium carbide is a rival of the agricultural product. If the rival becomes formidable, it is thought that much of France's interest in promoting the use of alcohol will disappear.

Admitting the possibility of methylated spirit cheapening; that carburetting may be free from danger; that the methylated spirit, in spite of the foreign substances mixed with it, may act well in the cylinder; that it may not foul the valves; and that it may give odourless combustion, as is hoped, even then its specific power will always be less than that of petrol spirit, whose only inferiority is the bad odour of the burnt gases, and this in the future, perhaps, may be prevented by a better system of combustion. There would be no question of alcohol as a substitute for petrol spirit did it not involve in France an economical point—namely, a market for a product of home manufacture. Nevertheless, alcohol (methylated spirit) has resolute advocates, and at their head is Petréano, who believes in the future of this fuel for automobiles, on account of its almost complete absence of odour in use, and because in the diffuser (p. 112) he employs to prepare the carburetted mixture the denaturing substances are separated and made to rest on the bottom like a kind of pitch, which needs removing only every twenty-four hours. The denaturing substances are heavy benzine and malachite green, and if these were vaporised they would interfere with the satisfactory employment of the alcohol, and would give malodorous residues. This diffuser also has the advantage of heating the carburetted mixture, and thus preventing separation of the cold alcohol when in contact with the hot cylinder. If this separation is not avoided, the cylinder wall must inevitably deteriorate by the formation of oxides; the presence in the exhaust box of scales of pulverulent substance when cold alcohol is employed leaves no doubt upon this point.

Many experiments have already been made with alcohol. In December, 1898, Commandant Krebs made brake tests with a Phœnix motor, altered by merely enlarging the ordinary inlet orifice; he obtained 3·6 h.p. with ordinary 95 per cent. alcohol, 4·2 h.p. with Dusart carburetted alcohol, and 4·4 h.p. with petrol spirit. The journal *Le Velo* organised, April 11th, 1899, a trial race for alcohol motors from Paris to Chantilly and back. Of the eight motor-cycles or cars on the list only one, Guttin and Co.'s, ran; it travelled the distance of 136 km. (84·5 miles) in eight hours eight minutes, the 4 h.p. motor consuming 38 l. (8·36 galls.) of alcohol, that is nearly 0·3 l. per km. (·85 pt. per mile). By way of comparison, it may be remarked that, according to experiments made by Brillié with a Gobron and Brillié car having a 6 h.p. motor weighing 850 kg. (1,874 lb.) in running order and carrying five persons (a very much heavier car than Guttin and Co.'s), the consumption under various road conditions was 0·14 l. (0·25 pt.) of petrol spirit per km. (0·62 miles), but this is thought to be below the average. These few experiments do not give anything conclusive, however. Périssé, in a communication to the French Society of Civil Engineers, has remarked upon the advantage of employing, instead of ordinary 90 per cent. alcohol containing 10 per cent. of common denaturing substances, the 95 per cent. alcohol made in all agricultural distilleries, or, better still, the 98 per cent. alcohol denatured with cheap hydro-carbons, which would enrich the explosive mixture. The motor should also be adapted to the new fuel, instead of employing an ordinary petrol motor.

Recent experiments have confirmed the statement that to get the best results alcohol motors should give a higher compression than petrol motors. Still, in practice it is desirable to have a motor that can work with either fuel, and this is generally possible by starting with petrol, and then when the motor is hot to turn off the petrol and supply alcohol only; for this purpose, of course, two distinct reservoirs and carburetters are necessary. The Wartburg (German) lurries work on this principle, as did also some of the cars taking part in the Circuit du Nord (p. 787) and the Paris-Vienna, 1902 (p. 788). On one German vehicle, at least, the conversion from one to the other is done automatically by a governor, which comes into play soon after starting and when a certain speed has been reached, and cuts off the petrol and turns on the alcohol; when bringing the motor to rest, the governor acts in the reverse manner, and the motor finishes as it began, on petrol. These last few strokes clear out the evil products of the combustion of the denatured alcohol, and so prevent injury to cylinder and piston head. The acetic acid and aldehyde resulting from burning alcohol imperfectly have been stated to quickly rust or corrode steel, but in the Paris 1902 alcohol trials, Sovel found only one clear indication of any such attack.

Perhaps, instead of alcohol, there will be a better chance of succeeding with the heavy distillery oils (0·75 amyl alcohol and 0·25 butyl alcohol), which, according to L. Lévy, always give, when mixed with the volume of oxygen, strictly necessary for their combustion, 4 horse-power hours per kg. (instead of 3·235 horse-power hours with alcohol and 6·75 horse-power hours with petrol spirit). As the oils cost only about 13·30 fr. per 100 kg. (0·57d. per lb.), the combustion of one franc's worth theoretically gives 30 horse-power hours (instead of 9 with alcohol and 15 with petrol spirit). The question as to whether their employment is practicable has not been answered yet, as not the slightest trial has been made.

There are some Deutz benzine locomotives in Germany, and the tramcars of the Saulgau-Herbertingen-Riedlingen line employ a 14 h.p. Daimler benzine motor. In that country, as far as can be judged from a yet insufficient practice, the benzine motor is about 10 per cent. cheaper than alcohol. Benzine is a bicarbide of hydrogen chiefly extracted from coal tars in gas works, and used almost entirely for the manufacture of aniline dyes; also, it is obtained from residual tar in coke-making by calcination and distillation of lignite, peat, wood, etc. Thus, it is much in demand, and a new application might possibly cause prices to increase and make it too dear for traction.

The employment of gas power may be mentioned very briefly. An American invented a motor, employing this material for the propulsion of bicycles. A receptacle filled with gas power and in immediate and intermittent communication with a cylinder where the material explodes, seems to be a permanent source of danger to the car, and this reason will suffice without giving any others for concluding that this motive agent can have but little future application for automobiles.

CHAPTER III.

STEAM BOILERS FOR AUTOMOBILES.

AUTOMOBILE boilers being intended (*a*) to be carried by the car, (*b*) to meet the variable exigencies depending upon the road and speed of the vehicle, and (*c*) to be entrusted to drivers only partly experienced, must fulfil the imperative needs of lightness, elasticity, and perfect safety by being (1) of small volume and weight though very durable, (2) easy to get rapidly under steam and of considerable power, this power being capable of easy regulation, and (3) easy to manage without risk of explosion. These qualities can be united only in boilers that are tubular, or that vaporise instantaneously. Some already existing boilers have been adapted to automobiles, and well-arranged new types have also been constructed. Both tubular and instantaneous vaporisation boilers have some features in common; these are: (1) To prevent smoke as much as possible they are fired with coke when petroleum or other heavy oil is not used; oil fuel, however, is now in common employment. (2) Like locomotives, nearly all have an artificial draught, produced by injecting exhaust steam into the funnel. Some of them have a blower, which is set to work when extra power is needed.

Tubular boilers are divided into two classes according as the tubes are to contain (*a*) fire, or (*b*) water and steam, and are called fire-tube boilers and water-tube boilers. Until recently fire-tube boilers were little used on automobiles, because whilst their very long horizontal tubes were no inconvenience with locomotives, they were a very great one with an ordinary vehicle; and vertical fire-tubes, now coming into extensive use, do not utilise the heat so well as horizontal tubes.

As regards fire-tube boilers, that of Leyland, employed by the Lancashire Steam Motor Company, is of this type. The tubes are vertical, and can be removed with the lid, so as to be conveniently cleaned. It is heated by a burner fed by crude petroleum under pressure of boiler steam, which, when the normal pressure is attained, partially closes the oil throttle valve, or air compressed overhead, as in the Leyland brake, which took part in the Versailles trials of 1898, whose results are tabulated on p. 367. The steam lurry (p. 522) sent by Leyland to the Liverpool trials of May, 1898, weighed, empty, 2,910 kg. (6,400 lb.), could carry a useful load of 4 tons, had a boiler which had a heating surface of 10·2 m.^{2} metres (110 sq. ft.), and weighed less than 30 kg. per m.^{2} (6 lb. per sq. ft.) of this surface. This boiler, tested at a pressure of 35 kg. per cm.^{2} (500 lb. per sq. in.), was constructed to give steam at 14 kg. per cm.^{2} (200 lb. per sq. in.), and it required 13 minutes to get up steam. It was fed by a brass hand pump, and on the roof was carried an air-condenser weighing only 43 kg. (95 lb.). At full charge the petroleum burnt per hour did not exceed 8 l. (14 pt.).

The old Coulthard boiler, as employed on the Coulthard lurry, is an example of the vertical fire-tube type. It is shown in section by Fig. 7. Its straight solid-drawn steel tubes are suitable for firing with either coke or coal, and the working pressure is 15·8 kg. per cm.^{2} (225 lb. per sq. in.); it is stated to be tested to a pressure of 31·6 kg. per cm.^{2} (450 lb. per sq. in.). The heating surface is 7·15 m.^{2} (77 sq. ft.), and the grate area ·25 cm.^{2} (2·75 sq. ft.). In the lurry the boiler is placed behind the front axle, so as to have more weight upon the rear wheels when running light, for increased tractive force, and to relieve the front wheels, and a further advantage is that the driver can see the ground immediately in front of the vehicle. The two safety check valves fitted to the boiler can be examined whilst the boiler is under steam.

The new Coulthard vertical fire-tube boiler, shown in vertical section and plan by Figs. 8 and 9, dispenses with the fire door beneath, though this is retained in the Brightmore boiler described next. This makes the Coulthard boiler more uniform, and the equal distribution of the metal in the shell ensures equal expansion and contraction, and minimises the risk of tubes leaking. The tubes are of solid drawn steel. The coal or coke is fed into the fire-grate through a central tube passing down through the water space. The smoke box has a conical top acting as a fuel receptacle, the fuel falling of itself into the furnace when the driver lifts the lid covering the central tube. The divided fire bars forming semicircular halves are mounted upon trunnions, about which they can be swung by hand. The ash-pan, divided similarly, is operated by a movement of the handle which releases the ash-pan, and if moved further drops the fire-bars. A damper frame is attached by the driver to suit the steam-raising requirements.

The Brightmore lurry, built by Messrs. Coulthard, has but a limited space available for the boiler, which is of the special construction shown in Figs. 10 and 11. It is of the vertical fire-tube type, containing 342 solid drawn copper tubes of 19 mm. (0·75 in.) external diameter, this being smaller than usual. There are nine tubular stays A. The grade area is 34·8 cm.^{2} (3·75 sq. ft.)

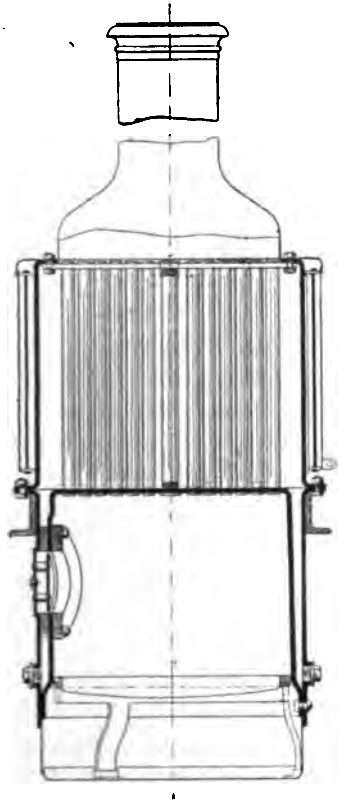


Fig. 7.

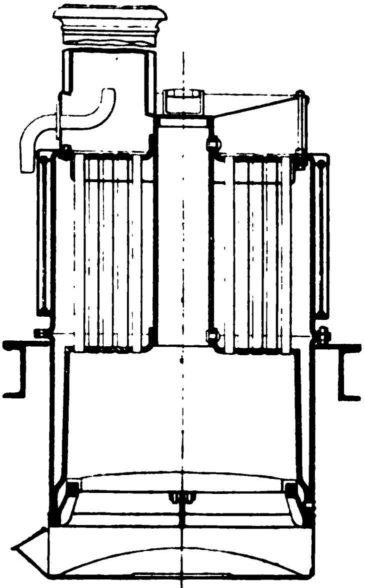


Fig. 8.

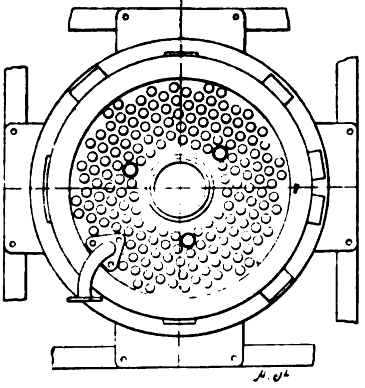
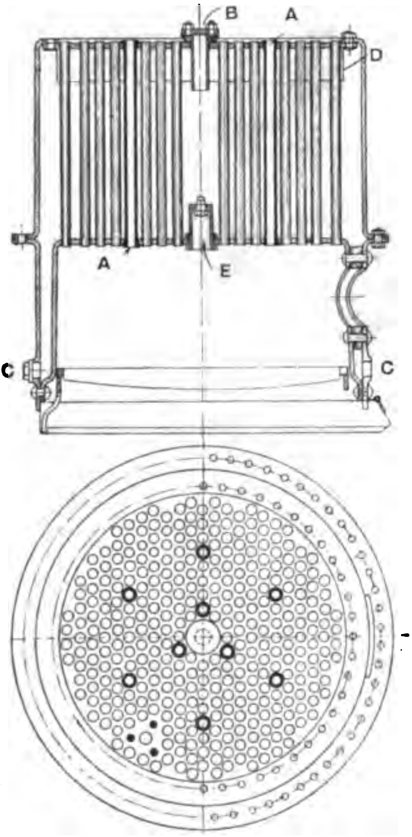


Fig. 9.

Fig. 7.—Coulthard Boiler (Old Type).

Figs. 8 and 9.—Coulthard Boiler (New Type).

and the total heating surface is 10 m.^{2} (108 sq. ft.). B is a wash-out attachment at the top, C three wash-out plugs at the bottom, and there is a blow-off cock. Between the dry plate D and the top of the boiler shell, the steam passes on its way from the lower part of the boiler to the throttle valve. To avoid risk of burning out in case of low water, there is a fusible plug E. The shallow fire-box is to be made deeper. The fire is controlled by a steam blast, and there are the usual dampers. Normal working pressure is 14 kg. per cm.^{2} (200 lb. per sq. in.). The fuel is coke, of which about 200 kg. (4 cwt.) can be carried. The boiler fittings, etc., are of the Coulthard type.



Figs. 10 and 11.—Section and Plan of Brightmore Boiler.

The House fire-tube boiler is of 10 h.p., and works at a pressure of 17·5 kg. per cm.^{2} (250 lb. per sq. in.), and it has been tested to twice that pressure. Its chief novel feature is a mud-trap, so termed by its inventor. A hand-hole in the top plate is covered by a detachable circular plate of 15·2 cm. (6 in.) diameter, through the centre of which the heated feed water is introduced. Two concentric tubes or cylinders are bolted to the underside of this plate, and extend to the bottom of the boiler, the outer one being closed at the bottom and perforated laterally near the top. The centre tube forms an extension of the water-feed tube, and is perforated by numerous holes all over, and it extends to near the bottom of the outer one. The feed water enters through the central tube, flows up between it and the outer one, and only when leaving the top of the latter does it enter the boiler proper. Any sediment is deposited between the two tubes, and when they are lifted out by means of the circular plate to which they are bolted it may be removed easily; and through the hand-holes then exposed the boiler tubes, arranged in radial lines round the boiler axis, can be cleaned.

The Chelmsford boiler (Clarkson and Capel) is of the vertical fire-tube type. Its shell is of steel, and in one piece with the top plate, whilst the bottom plate is flanged around its edge and riveted in place. It contains about 512 solid drawn steel tubes, of about 22 gauge and 14·2 mm. (0·56 in.) external diameter, and all these are expanded into the top and bottom plate. The normal working pressure is 17·5 kg. per cm.^{2} (250 lb. per sq. in.), and the boiler has been tested to three times that pressure. It is heated by an improved Clarkson burner, to which the fuel feed is regulated automatically by the boiler pressure. It takes 12 minutes to get up steam.

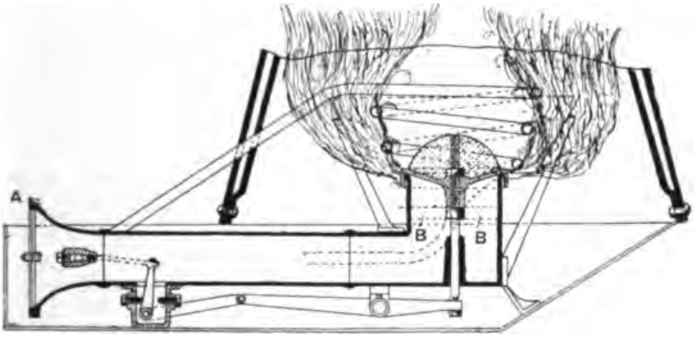


Fig. 12.—Clarkson and Capel Burner (Old Type).

The Clarkson and Capel liquid fuel burner (Fig. 12), employed on the early heavy vehicles made by that firm, is of the true Bunsen type, and consists essentially of a vaporiser, a regulated jet, an inducing tube, a mixing chamber, and a regulated orifice at which the vapour issues and is burnt. The vaporiser is a spirally coiled steel tube through which oil passes on its way to the jet; to prevent overheating, the coil is not in contact with the flame. The force of the vapour issuing from the jet induces with it a supply of air, the two becoming thoroughly mixed in the mixing chamber B B. A special regulating device for the air is not required, but the damper A is provided at the end of the inducing tube for use with forced draught and in starting the burner A perforated nickel cone, shown, surrounds the orifice at which the flame issues, its object being to improve combustion and act as a radiator and igniter in case of the burner being blown out.

The Clarkson burner used on the Chelmsford steam car does not differ materially from the above, but it contains a few improvements. For instance, the vaporising coil is a steel tube wound round with nickel wire to prevent oxidation of the steel; the flame of the starting lamp plays upon one end of this coil; the burner is a casting containing an asbestos wick; a measured quantity of oil is taken up by an asbestos wick, and then is ignited by dropping in a match through a small door at the top, and a clockwork fan then causes the lamp to burn and the flame to be concentrated upon the vaporising coal. The fuel feed pressure usually is maintained at 2·8 kg. per cm.^{2} (40 lb. per sq. in.), and this high pressure, together with a special throttle, prevents the burner "surging." Reference to Fig. 13 will make clear the construction of the new Clarkson burner. In that figure, A is the vaporiser, B the main burner, C a subsidiary burner, D the asbestos-lined casing or envelope of the vaporising tube, and E the door through which the light is inserted for igniting the burner. Oil is supplied to the subsidiary burner through pipe F, having a valve or cock G controlling the

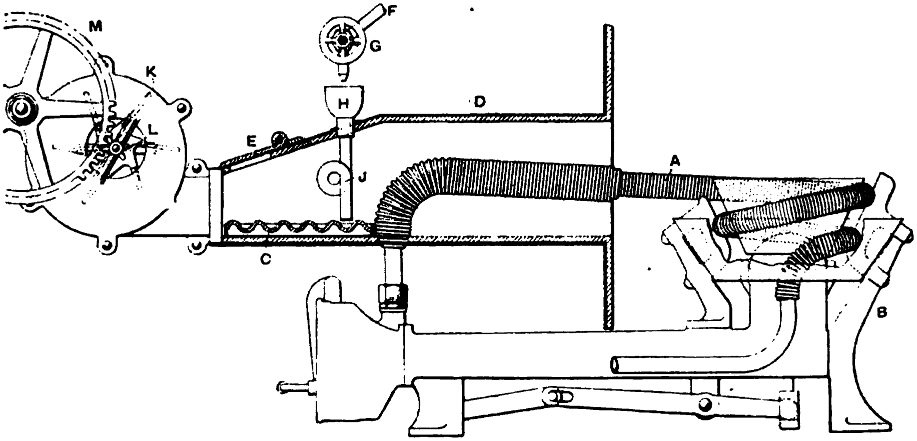


Fig. 13.—Clarkson and Capel Burner (New Type).

delivery of the fuel to a cup, H; tube J delivers oil from the cup to the wick of burner C. K is the fan or blower, on whose shaft is mounted a toothed pinion, L, gearing with the hand-operated wheel M.

The Chelmsford automatic fuel regulator employed in connection with the improved Clarkson burner is shown in elevation by Fig. 14, and in vertical section by Fig. 15. Its lower portion forms a cylinder for the plunger or piston A, a steam pipe for the boiler being led to the bottom of it. The piston A with rod B is kept down by the spring C. Steel rods join the top to the bottom, and the piston rod B is connected by adjustable nuts with a cross piece engaging with the short arms of a pair of bell-crank levers D. The levers are fulcrumed at the ends of the piece E, and the longer ends are connected with the device which regulates the fuel and air supply to the burner. As the steam pressure rises, it lifts piston A, compressing spring C, and causes the levers D to move about the fulcrum E, and so reduce the size of the flame.

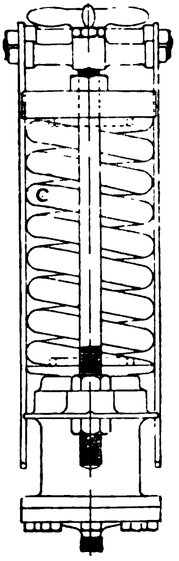


Fig. 14.

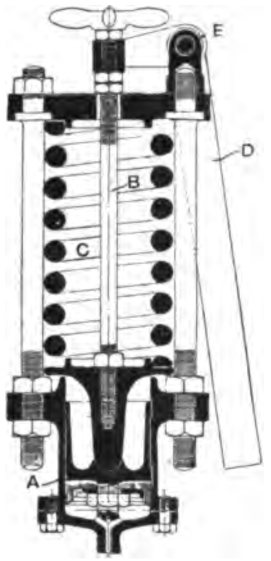


Fig. 15.

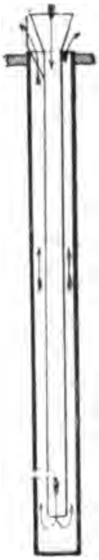


Fig. 16.

Figs. 14 and 15.—Chelmsford Automatic Fuel Regulator. Fig. 16.—Tube of Bollée Boiler.

Water-tube boilers will now be considered. The patent for the

Ravel boiler and the tricycle it worked dates back to 1868, and is mentioned as a matter of history only. This boiler was heated with petroleum, which now is adopted in most of the modern types. A worm pipe, with its coils joined, was placed inside a cylindrical jacket, terminated on top by a hemisphere. The burnt gases ascended in the centre of the worm, and descended between it and the jacket, passing thence to the funnel. The water fed into the lower part of the jacket ascended to the top, and then descended to enter the lower part of the worm, flow through, and pass out at the top. The steam collected in a large compartment formed by an annular cylindrical jacket filled with hot gases, where it was slightly superheated, though remaining at a low pressure. In short, it was a rapid vaporisation boiler, with a sufficient amount of water and a large reserve of steam ; it had to have a water gauge and other apparatus.

The Amédée Bollée boiler is merely the Field boiler of the fire-engine type. As this type is well known, it will suffice to recall that the body is formed of an annular cylinder surrounding the fire-box and funnel, the inner diameter of the top part around the funnel being smaller than the lower part, which corresponds with the fire-box, so that there is an annular crown over the latter. This crown acts as a support for the tubes, which dip horizontally into the fire-box, so as to impede the passage of the gases to the funnel and thus increase the surface in contact with these gases. Inside these tubes there are other concentric tubes; the water descends through the inner tubes and ascends through the spaces left between the two sets of tubes as shown in Fig. 16 by the arrows—the result being that vaporisation is very rapid. Unfortunately the tubes are liable to become burnt and also to scale. To avoid scaling, only the purest of water should be used. The boiler of *La Nouvelle*, the omnibus which ran in 1895 from Paris to Bordeaux and back (*see* p. 765), had an outer diameter of 70 cm. (27½ in.), and contained 118 tubes. About 30 minutes was needed to get up steam.

The Scotte boiler, Fig. 17, also belongs to the Field type, but it has been much improved, especially by the additions of a water-stirring tube, a detartarising heater, a super-heating dryer, a blower, a movable grate, and a flue orifice, the advantages of which are explained later in connection with the illustration.

The boiler of the Scotte omnibus and traction engine weighs from 400 kg. to 500 kg. (from 880 to 1,100 lb.) empty, and carries from 50 l. to 60 l. (11 gal. to 13 gal.) of water, the hourly consumption, with a grate—which has a heating surface of 0·13 m.^{2} (1·4 sq. ft.) in the small model, and 0·15 m.^{2} (1·6 sq. ft.) in the large model—is 40 kg. to 45 kg. (88 lb. to 99 lb.) of coke, with a production of about 220 kg. (485 lb.) of steam, at a pressure of 12 kg. per cm.^{2} (200 lb. per sq. in.). It can feed a motor from 12 to 16 h.p., and getting up steam takes from 35 to 40 minutes, but this can be accelerated by employing the blower.

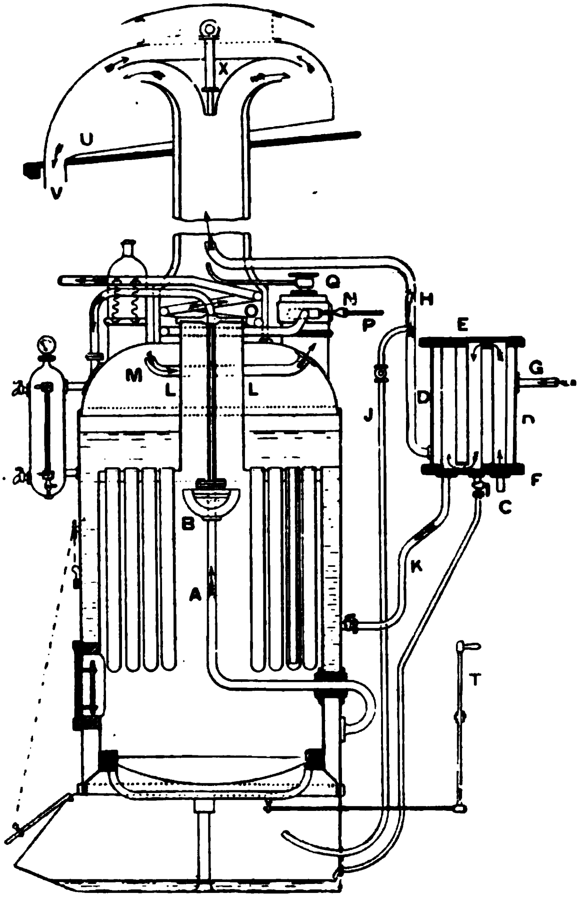


Fig. 17.—Scotte Improved Field Boiler.

In Fig. 17, the illustration of the Scotte improved Field boiler, A is the water-stirring tube connecting the lower part of the annular space formed by the two sides of the boiler near the feed hole with the steam dome; it provides a direct path by which the relatively cold water flowing into the boiler can reach the highest part, thus keeping the temperature of the boiler more uniform, and decreasing the inequalities of contraction and consequently the strain on the metal, whilst the flow of water being accelerated the heat is better utilised. B is a fire-clay guard which protects the joint of tube A from the heat of the fire-box, and which makes the smoke lick the hanging tubes more thoroughly before reaching the funnel. C is the feed-water inlet to the detartarising heater D, which is formed of brass tubes united by the head plates E and F. G is the admission for the motor exhaust steam around the tubes, this steam heating the feed water and passing to the funnel through pipe H. On this the tube J is branched, and when a cock is opened it conveys part of the steam under the grate to accelerate the draught. The water, which should be purified if it shows more than 20° by the hydrometer, loses some of its earthy contents in the detartarising heater and there acquires a temperature which may be as high as boiling point, 100° C.; thence it enters the boiler through pipe K. The steam thus produced, already heated by tube L, runs through tube M into box N, which the regulator worked by lever P can place in communication with the coil O, heated by the gases from the fire-box; there the steam dries, and is superheated before passing to the motor. Part of it can be drawn off by the blast cock Q and conveyed into the funnel to further increase the draught. The grate, which is circular, can by aid of the lever T be made to move with an alternating rotary motion around its vertical axis. It is lower down than represented at the top part of the ash-box in Fig. 17, and for firing can be brought near the ash-box bottom, which is occupied by water condensed from part of the exhaust steam in the heater D, and brought by the pipe L. This liquid cools the bars of the grate by vaporising under the influence of the hot cinders which drop out. The sparks rising in the funnel are stopped by the guard X, which prevents them from getting outside, and they then fall back on to the inclined plane U, and reach the ash-box through pipe V.

The Thirion and Durenne boilers, especially the former, are very similar to the Field boiler adapted to fire-engines, to the Westinghouse horizontal tube boilers, and to the Rowan, with tubes slightly inclined for the traction of locomotives and tramcars. Thus it appears they might be adapted easily to cars.

The de Dion-Bouton boiler is an ingenious type, nearly twenty years old, specially invented for automobiles. The 1897 type has two concentric shells of annular section, connected by small diameter steel

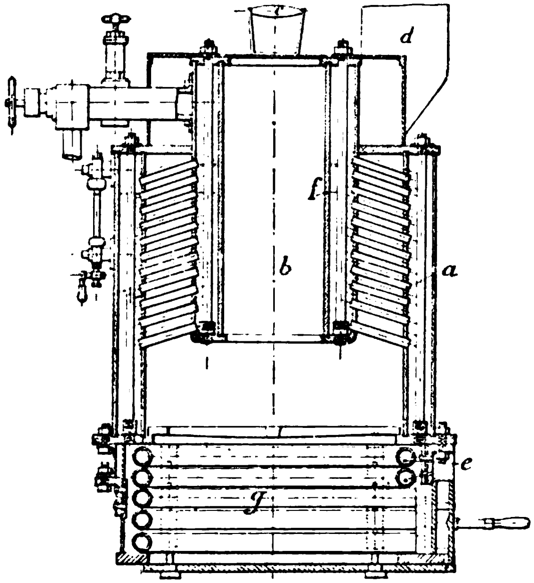


Fig. 18.—De Dion-Bouton Boiler.

tubes, *a*, Fig. 18, inclined upwards from the outside shell. The length of these tubes does not exceed twenty times their diameter, so as to avoid the formation of pockets of steam, which are dreaded in many multitubular boilers. The two shells are about the same length, though their bases are not at the same level. The larger forms the outer jacket of the fire-box, the central tube *b* is a fuel box, filled with coke through the top *c*, opening with a lid. This method of charging with relatively large quantities makes it possible to leave the fire-box for a very long time without new supplies. The gases of combustion rise through the spaces between the small tubes *a*, and as these spaces are small and tortuous, owing to the baffle arrangement of the tubes, the gases are so deprived of their heat that when they reach the smoke-box at the top of the boiler their temperature is not more than 250° to 300° C. From the smoke-box they escape by the funnel *d*, generally bent so as to discharge at the back of the car. As the gas emitted may make it difficult to inspect the car, and, in particular, to repair the motor during stoppages, the funnel has its outlet on the roof, when the car has such an addition, as in the case of an omnibus. The water is conveyed to the boiler by means of a pump or Giffard injector, and is maintained at a level situated below the diaphragm *f*, which is itself below the two top rows of tubes, so as to cut off communication between the higher and lower parts of the inner cylindrical body. The water fills the tubes, and consequently is divided into small volumes licked all over by the flame and gases of combustion, the water being heated rapidly. This has a double advantage:—(1) Each tube is thus traversed from the outer to the inner cylinder by an intense current, whose force is an obstacle to the formation of boiler-scale. (2) The vaporising power of the boiler is very great. The rapidly formed steam contains a certain amount of water which can be got rid of with advantage. The steam dries in passing through the two higher rows of tubes, which, as stated above, terminate above the diaphragm and the pipes in the smoke-box. Sometimes, as in the boiler, Fig. 18, employed for the de Dion-Bouton omnibus and traction engine at the Versailles Poids Lourds trials of 1897, a steel wire, *e*, is inserted between these pipes and the steam valve which surrounds the fire-box; in this worm the steam dries, and even becomes superheated. The worm *g*, shown below the preceding, is to superheat the exhaust steam; in this way this steam, which is again re-heated through mixing with the hot gases of combustion found in the funnel, is almost invisible when it escapes into the air. Of course, the boiler is provided with a safety-valve, a steam-gauge, a water-gauge, gauge and blow-off cocks. There are two doors to admit of the fire-box being cleared out and the ash-box emptied. The de Dion-Bouton boilers can be made for a power of from 2·5 h.p. to several hundred horse power. For automobiles the power varies from 5 h.p. to 35 h.p., and the boilers are registered at 18 kg. per cm.^{2} (256 lb. per sq. in.) for a normal pressure of 14 kg. per cm.^{2} (200 lb. per sq. in.); in this case they are hardly 1 m. (39·3 in.) high by 0·7 m. (27·5 in.) in diameter.

The Weidknecht multitubular boiler, Figs. 19–22, was made entirely of steel, with internal fire-box charged automatically, and furnished with a superheater. The grate was in two parts, the back being fixed and the front movable by means of a set of rocking levers which, when lowered, allowed the fire to be partially thrown out so as to clean the fire-box without need of completely emptying it. The whole was inclined, and the fuel reached the fire-box from a charging hopper placed in front of the boiler. Vertical tubes connected the crown of the fire-box with the base of the funnel, the better to utilise the fuel. The water tubes were slightly inclined horizontally to aid the release of the steam, and terminated at each end in plates which facilitated cleaning and replacement. Feeding was accomplished by a Sellers suction injector and an automatic pump, the delivery of which could be regulated by adjusting a valve in the return water pipe, which was

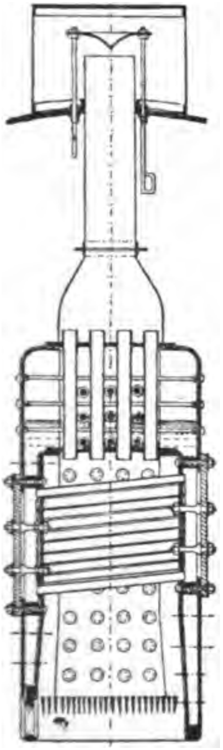


Fig. 19.

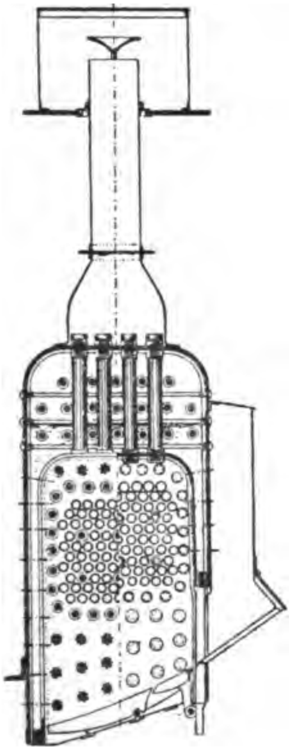


Fig. 20.

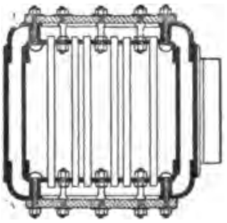


Fig. 21.

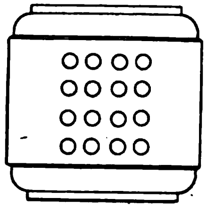


Fig. 22.

Figs. 19 and 20.—WEIDKNECHT BOILER: VERTICAL SECTIONS. Fig. 21.—HORIZONTAL SECTION. Fig. 22.—PLAN.

branched on the feed pipe. The boiler of Weidknecht's 16-seat omnibus, constructed to carry 500 kg. (1,100 lb.) of luggage, had a grate surface of 27 dm.^{2} (3 sq. ft.), a heating surface of 6 m.^{2} (64·6 sq. ft.), 87 tubes of 33 mm. (1·3 in.) outer diameter, it gave 260 kg. (573 lb.) of steam per hour at an average pressure of 12 kg. per cm.^{2} (170 lb. per sq. in.), and was registered for 15 kg. per cm.^{2} (213 lb. per sq. in.).

The Nègre boiler, a type for heavy cars, is shown diagrammatically by Fig. 23, where F is the fire-box and B the cylindrical body, the steam and water being between the two. To light the coke fire the damper R is opened, to be closed again when the fire is well alight; the burnt gases cannot pass to the chimney except by the winding path marked by arrows in Fig. 23. The feed water follows the opposite direction, entering a worm, *s*, *s*, which carries it into the top of the boiler B. It gradually absorbs the heat given up by the gases of combustion, and completes its vaporisation on entering the tubes, heated directly by the fire. This boiler gave 6·5 kg. (14·3 lb.) of steam at a pressure of 14 kg. per cm.^{2} (200 lb. per sq. in.) per kg. (2·2 lb.) of coke; the ordinary type vaporises as much as 286 kg. (616 lb.) of water per hour.

The Turgan boiler consists of a horizontal cylinder forming the top edge of a triangular prism, the sides being formed by the inclined water-tubes, and the base by the horizontal grate. Each tube is double, as shown by Fig. 16, p. 45, and the outer tube opens at its top end into the cylinder, and at the base is closed by a screw plug outside the fire. The inner tube opens at both ends, the top into a collector inside the cylinder, and the bottom near the base of the outer tube. The boiler is fed entirely from the higher collector, the water descending through the inner tubes, and rising through the annular space between them and the outer tubes. The flames and hot gases are directed by guards, which form wide tubes, touching each other. A boiler with heating surface of 15·5 m.^{2} (167 sq. ft.), and grate surface of 0·6 m.^{2} (6·5 sq. ft.), weighs 900 kg. (1,980 lb.), is 0·85 m. (33·5 in.) long, and 1·2 m. (47·2 in.) wide, dome included. According to the inventor, the efficiency with forced draught exceeds 7·5 kg. (16·5 lb.) of steam per kg. (2·2 lb.) of coke; a good fire in the boiler produces 750 kg. (1,650 lb.) of steam per hour, and the production may attain 1 000 kg. (2,200 lb.) with very strongly forced draught.

This boiler was employed by Turgan and Foy for a steering driving fore-carriage (p. 573).

The Thornycroft new water-tube boiler is shown by Fig. 24. It is constructed wholly of steel, and is of the Thornycroft patent central-fired, steam-wagon type, having straight water-tubes arranged circularly around the fire. The total heating surface is 12·26 m.^{2} (132 sq. ft.), and the grate area is 0·39 m.^{2} (4·25 sq. ft.), and the working pressure is up to 15·8 kg. per cm.^{2} (225 lb. per sq. in.). Coke or coal is used as the fuel, which is introduced through the central firing-hole of the top vessel; regulation is obtained by a hinged door in the ashpan and by the firing-hole cover. Plugs and blow-off cock are fitted from the bottom of the boiler for cleaning out, and the fire can be clinkered through a special and easily accessible hole on the left-hand side. The top of the boiler can be removed for cleaning the insides of the tubes, whose outsides are cleaned by a

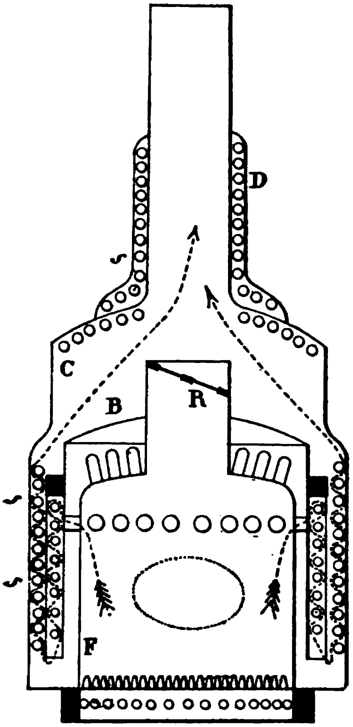


Fig. 23.

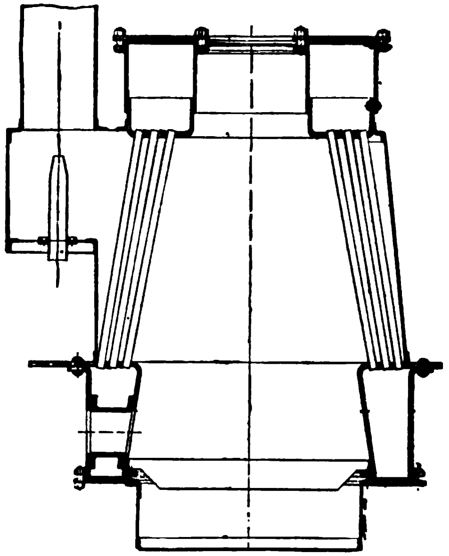


Fig. 24.

Fig. 23.—Nègre Boiler for Heavy Vehicles.

Fig. 24.—Thornycroft Boiler.

steam jet, the side casing being taken down for the purpose. On the right-hand side of the boiler is a throttle valve having a long spindle operated by a hand wheel. One of the two safety valves lifts if the normal working pressure is exceeded; and the other, set at about 0·7 kg. per cm.^{2} (10 lb. per sq. in.) above normal pressure, rises in the event of the first failing to act. When the vehicle is in motion the boiler is fed by a pump driven directly by the engine, and when stationary the engine may be disconnected from the transmission gear and run free, thus feeding the boiler; or the feed water may be supplied by an injector of special pattern mounted on the boiler itself. The injector is so designed that the cones may be removed for examination while the boiler is under steam. Fuel is economised by heating the feed water by the exhaust steam.

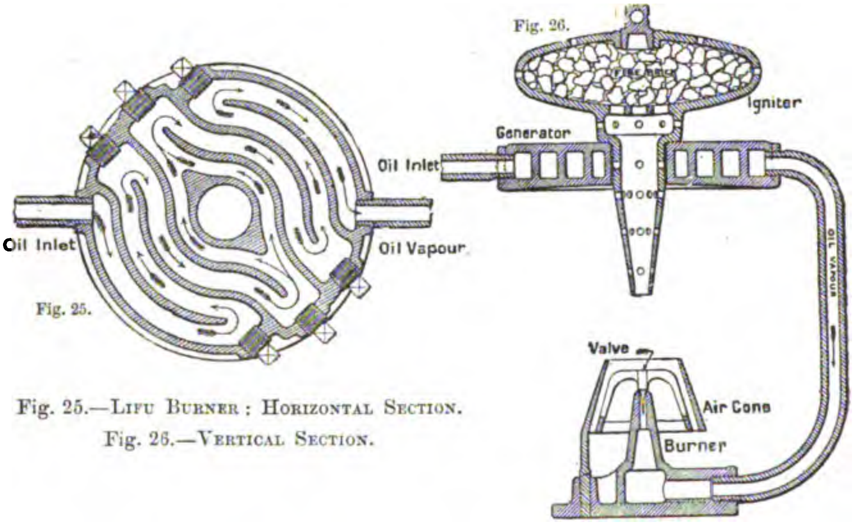


Fig. 25.—Lifu Burner: Horizontal Section.
Fig. 26.—Vertical Section.

The Lifu boiler was used by the Liquid Fuel Engineering Company, Cowes, Isle of Wight. The tubes, grafted on a lower horizontal ring, rise vertically and then bend slightly, still remaining nearly as a vertical cylinder, and finally the tops enter the bottom of a cylinder concentric with the lower ring, but above it, and smaller in diameter, thus forming a steam chest. If the tubes shown in Fig. 27 were wound spirally on a cylinder without the top horizontal boiler, that illustration would fairly well represent a Lifu boiler. The joints are made with check nuts, which facilitate replacement or temporary plugging of a burst pipe. The boiler is heated by using ordinary petroleum in a special burner, shown by Figs. 25 and 26, which two figures are self-explanatory. The delivery of petroleum is regulated automatically by steam pressure. The iron receptacle seen over the burner is filled with materials which can retain heat for a long time, and these re-light the burner when extinguished by the wind or any water contained by the oil. For an engine of 35 indicated h.p., with a normal development of 25 h.p., the boiler has a heating surface of about 7·5 m.^{2} (79 sq. ft.). The safety valves are regulated for a pressure of 18 kg. per cm.^{2} (256 lb. per sq. in.), and the pipes have been tested for double this pressure.

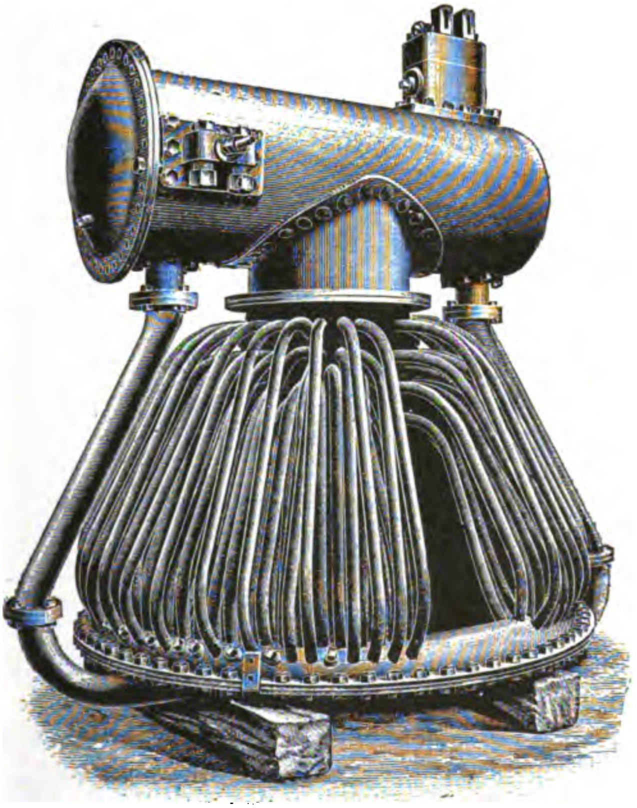


Fig. 27.—GILLETT BOILER.

The Gillett boiler is employed by the Motor Omnibus Syndicate, and an idea of its structure is given by Fig. 27. The fuel is coke. The boiler is partly fed with water of condensation from the exhaust steam, by aid of an injector and two pumps. Normal pressure is 14 kg. per $cm.^2$ (200 lb. per sq. in.). The makers state that steam is got up in 6 minutes, but this is improbable.

The Freadley boiler has horizontal tubes, and is heated with either coke or petroleum, coke being very satisfactory, and the boiler is fixed to the frame of the vehicle by springs to prevent jolting.

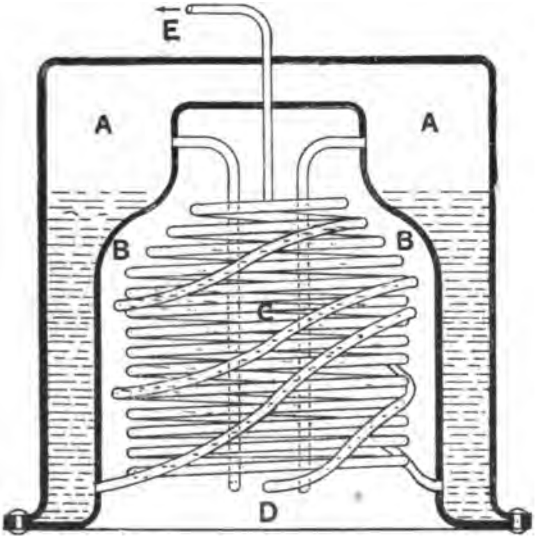


Fig. 28.—Toledo Boiler.

The Spencer (American) water-tube boiler is of special construction; it comprises eight shells of tubes, each surrounded by a circulating coil, the shells being joined together at top and bottom. Circulation is rapid, and sediment is removed by blowing off. Its heating surface is 4·18 $m.^2$ (45 sq. ft.), and it is 56 cm. long, 30·5 cm. wide, and 45·7 cm. high (22 in. × 12 in. × 18 in.). Paraffin is the fuel. The boiler water feed is controlled by a float-feed mechanism resembling that in a popular form of carburetter. An aluminium float is mounted in a vertical supply pipe, and this rises when the required level is reached.and cuts off the supply, a bye-pass at the same time opening and allowing the water to be pumped back into the water tank.

The Toledo water-tube boiler (Fig. 28) has one shell (B) within another, the chamber, A, between them forming an annular water space. Within the inner shell several lengths of weldless steel tube are wound spirally to form a central coil C; the ends of the tubes are fitted into the inner shell at top and bottom. The burner flame at D passes up between these tubes and causes rapid circulation, which prevents any deposit forming except at the bottom of the annular space. There are small dams or scoops at the mouths of the tubes, where they open into the annular water space. The steam is taken from space A, superheated within the coil C, and passed to the motor through pipe E. The working pressure is from 14 kg. to 17·5 kg. per cm.^{2} (200 lb. to 250 lb. per sq. in.), and the boiler is tested to 42 kg. per cm.^{2} (600 lb. per sq. in.).

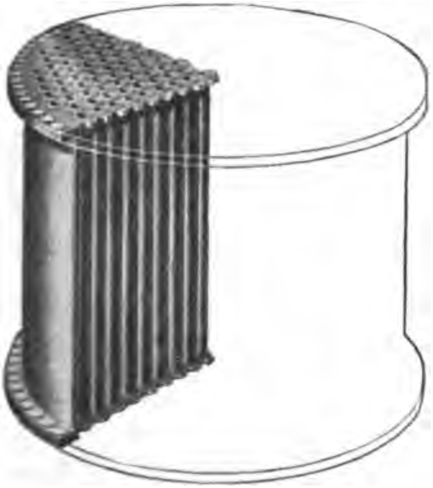


Fig. 29.—Weston Boiler.

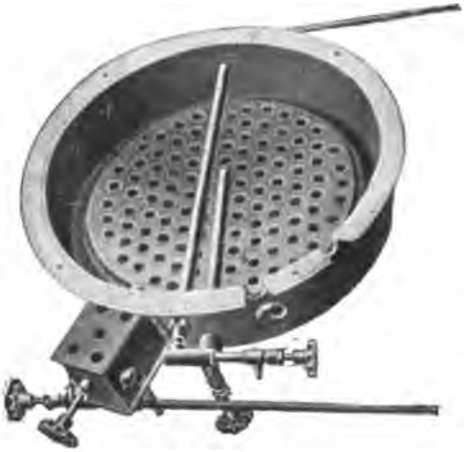


Fig. 30.—Weston Burner.

The Weston (American) (Fig. 29) is an extremely simple, well made fire-tube boiler. The cylindrical shell and tubes are of copper, the tubes being secured into steel end plates. Its heating surface is 4·2 m.^{2} (45 sq. ft.), and is tested to a cold water pressure of 42 kg. per cm.^{2} (600 lb. per sq. in.). A safety valve blows off at a pressure of 15·8 kg. per cm.^{2} (225 lb. per sq. in.). The burner (Fig. 30) is of more particular interest. Two separate supply pipes lead to it, one feeding the pilot light, which heats the vaporiser tube, and the other leading through the vaporiser to the main burner. The driver regulates the fuel feed, and automatic devices are not used. For lighting the burner, a little petrol spirit is allowed to flow into the receptacle beneath the pilot lamp, which resembles an ordinary plumber's blow-lamp. The petrol is lighted, and as soon as the lamp is heated sufficiently, petrol is fed to it at a constant rate. The flame of the pilot lamp plays on the vaporising tube which passes diagonally across above the burner. Its end farthest from the pilot lamp is heated by the burner itself. A steel cable inside the tube acts as a distributing baffle for the main fuel feed and increases the heating surface of the vaporiser. Economy is effected by having the few burner jets beneath the further end of the vaporiser tube, which then is heated more highly when a larger quantity of spirit is to be vaporised, and is less highly heated when the main feed is cut off.

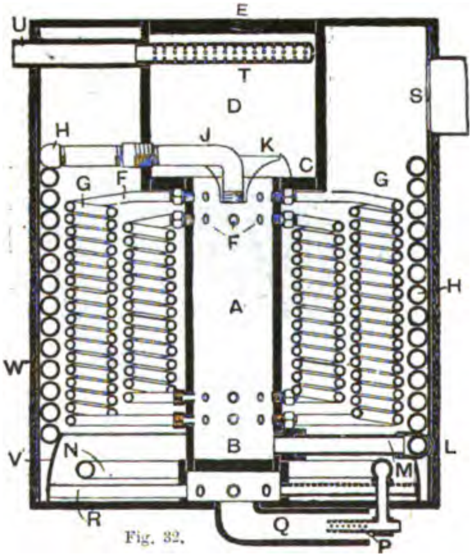


Fig. 32.

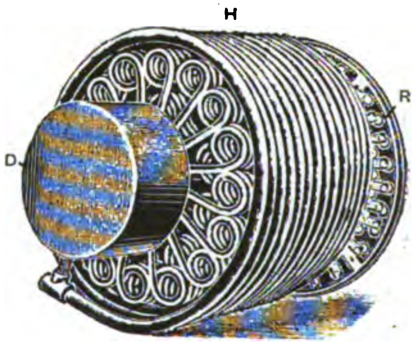


Fig. 31.

Figs. 31 and 32.—General View and Section of Salamandrine Boiler.

The Salamandrine tubular boiler, invented by Ofeldt, an American, is shown in general view, the outer case removed by Fig. 31, and in vertical section by Fig. 32. It is the result of an attempt to adhere to the old principle of water tubes as against the modern "flash" generator, whilst avoiding the risk of burning out at low water and the difficulty of cleaning, the two chief disadvantages of tubular boilers. A great point is gained if these disadvantages can be overcome whilst retaining the inherent advantage of power storage; besides, the tubular boiler does not necessitate so close a synchronism between the generation of steam and the demands of the engine. The construction of the Salamandrine boiler is curious. A central tubular shell, A, closed at the bottom by plate B, and carried at its upper end by a plate, C, forms the extension of a circular steel drum, D. The top of the drum is the plate E. Coiled tubes F and G are arranged around the central tube, to which they are connected top and bottom. The coils G form a circle outside coils F. Each of these vertical coils connects the upper portion of the central tube A with the lower portion. A tube, H, is coiled or wound concentrically round the series of coils F and G, and its upper end communicates with the central tube by means of a pipe, J, to the bent portion of which is fixed a deflector plate, K; this plate baffles the passage between the central shell A and the drum D to a certain extent, and prevents water being carried up from one to the other. The feed water, fed into the lower end of the outside coil H by pipe L, is led to the top of the central tube A; but also it can pass direct through pipe M to the bottom of the central tube. The outer coil acts as the feed-water heater, and the inner series of coils as the steam-raising and superheating tubes. The central shell screws into the centre of the burner, which forms a supporting base for the boiler. The petrol spirit is fed through the vaporising tube N down to the nozzle P; around this air enters into pipe Q, mixes with the spirit vapour, and passes to the tubular chamber R, which has a number of radial tubes; the fuel issues from holes in their upper surfaces, and is here ignited. The flames heat the vaporising coil N, and pass up around both the inner and outer coils F, G, and H. The hot gases also surround the steam drum D before passing to the flue S. From the steam drum the steam passes through the perforations T, and then to the motor through U. The baffle K and perforated pipe T ensure the dryness of the steam. The burner is surrounded by a plate V which deflects the heat on to the inner coils. The boiler casing W forms what may be termed the snake box; it is easily removable without interfering with the rest of the boiler, and is made of asbestos riveted to sheet iron.

The Salamandrine boiler is made in three sizes: 6 h.p., 52 cm. (20·5 in.) high, and weighing 82 kg. (180 lb.); 10 h.p. 57 in. (22·5 in.) high, and weighing 132 kg. (290 lb.); 25 h.p., 112 cm. (44 in.) high, and weighing 204 kg. (450 lb.). The normal working pressure (said to be attained in 2¼ minutes) is from 14 kg. to 17·5 kg. per cm.^{2} (200 lb. to 250 lb. per sq. in.), and the boiler is tested to a pressure of 49·2 kg. per cm.^{2} (700 lb. per sq. in.). In a public test conducted in America the water was allowed to wholly evaporate, and in a few minutes the bottom was heated to cherry red; then cold water was admitted, and normal pressure obtained without any leak showing. The boiler that underwent this test a number of times has a central shell 12·7 cm. (5 in.) in diameter, and 40·6 cm. (16 in.) long; a steam drum 25·4 cm. (10 in.) in diameter and 12·7 cm. high; 24 inner coils about 7·6 cm. (3 in.) in diameter, and made of 3·2 mm. (0·125 in.) bore pipe; and an outer coil of 12·6 mm. (0·5 in.) bore pipe. It may be said that there are slight differences between the boiler just described and the very latest construction, in which the inner coils are slightly tilted to better catch the heat, this being said to increase the steam output by 10 per cent.

Instantaneous vaporisation or flash boilers contain only a minimum amount of water, so there is no serious danger of their exploding; for this reason, they do not require any safety valves, gauges, and such appliances.

The original flash boiler, a very old invention, was a large cast-iron pot made red-hot, into which water was sprayed, and falling on the hot iron was instantaneously "flashed" into steam, the object being to send in just so much water at each stroke of the engine as would supply steam for the next stroke. In another form of flash boiler mercury was kept at a high temperature, and the water was dropped on it to flash into steam. Objection has of late been raised against the use of the term "flash boilers" in connection with boilers of the small, long tube, or Serpollet type. These, it has been argued, are not flash boilers at all, though, as the *Engineer* says, it is not easy to find a better or more compact name.

A description of the well-known Gardner-Serpollet boiler may well be preceded by an enunciation of its principles and some notes on its operation. The boiler is an arrangement of conveniently converted steel circular tubes of varying thickness, around which in an upward direction heat from a paraffin burner can pass and be equally distributed about them. The cold water pumped into one end is converted into steam on its way through the one continuous tube. Only the quantity of water that can be converted during its passage into highly superheated steam should be supplied; if the supply of water is in excess and beyond the capabilities of the boiler to vaporise and superheat, then the working is inefficient, and, on the other hand, if the heat is too much and the supply of water too little, the tubes may be damaged mechanically from overheating.

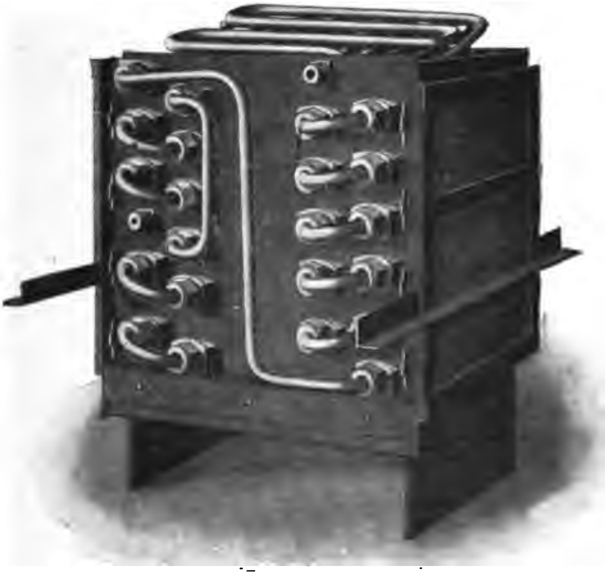


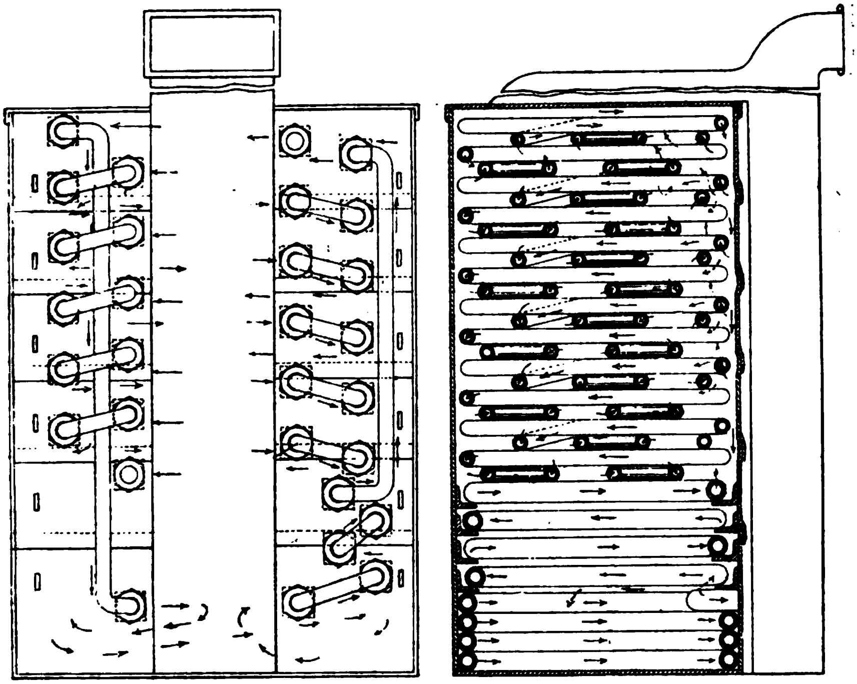
Fig. 33.—English Serpollet Boiler.

Of course, the heat given by the burner varies with the amount of fuel supplied, but there is a limit to it. The water introduced into the boiler tubes tends to cool them, and theoretically should take up the whole of the burner heat produced. Therefore the amounts of water and fuel should be proportioned to one another, so that precisely the correct quantities are delivered at all times; otherwise, the evils indicated above will make themselves evident.

In the Gardner-Serpollet system the difficulty is overcome by connecting both the water and fuel feed-pumps by the same rocking lever, this being rocked according to the quantity of steam required by the motor. After adjustment, the fuel feed accommodates itself to the water feed. This is the most distinctive feature of the Gardner-Serpollet system. The feed-pumps are operated by the motor, and hand-regulated by the driver. For starting, it is necessary to provide other means of feeding the boiler and burner. By means of a hand-pump a slight air-pressure is obtained in the fuel tank, the oil, in quantity depending on the pressure, finding its way past the pump check valves. This furnishes sufficient heat to generate a small quantity of steam. The water for starting is hand-pumped into the boiler, and is converted instantly to steam; as soon as the motor starts it operates the combined feed-pumps, and further maintenance is automatic, the driver regulating the pump throw to get sufficient steam.

There are, of course, points in the operation of the Gardner-Serpollet boiler which are common to all "flash" generators. Even with only a small fuel supply, the burner can heat the tubes to a temperature considerably higher than that of superheated steam if the tubes have not to give up their heat to any water passing through them; thus comparatively little heat can convert a few drops of water per minute into highly superheated steam. Naturally, if the water feed is increased, the fuel feed must be also if the steam is to reach the same temperature. The amount of fuel consumed by the burner in a given time is limited, but whatever it is it must have a proportionate quantity of air to support its combustion. In a flash boiler, then, the amount of water which it is capable of converting to superheated steam is limited, and with even the maximum burner heat the resultant steam will be wet and of low pressure if the water feed is excessive. The Gardner-Serpollet boiler superheats steam to 427° C. (800° F.), but the temperature of the tubes if they were at cherry-red heat would be about double this. Remembering these simple facts, it is easy to understand why superheated steam of about the same temperature is generated in these boilers, irrespective of the amounts of fuel and water supplied to them and of the amount of steam supplied by them.

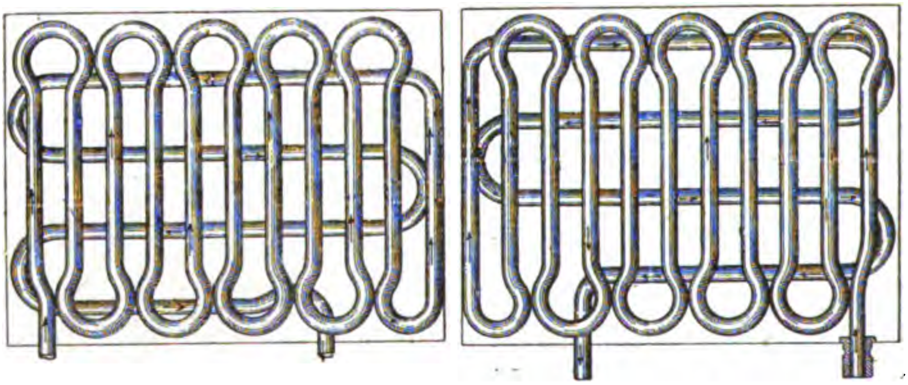
A recent article in the *Engineer* stated some of the disadvantages of flash boilers of the Serpollet type, As there is only a most limited steam space and water reserve, it is evident that whatever goes on in the pump is immediately reproduced in the boiler, and whatever takes place in the boiler at once affects the engine. Thus, if the pump misses a few strokes, the water level will instantly descend in the tube, the tube will become hotter, surfaces will become dried, and when the pump again throws water the surface may refuse to be wetted, and so the whole balance is upset. (It appears to be by no means easy to keep the surface of highly heated tubes wetted; a spheroidal condition may be set up, but what is more, some kind of repulsion appears to be produced between the metal and the water.) Or, again, the pump may throw too much water, with the result of lowering the temperature and possibly drowning the engine. In the same way, all going on steadily, the fire is suddenly urged; the result is that the water is now evaporated faster than the pump sends it in, and a large portion of the tube may become dry. The whole operation of generating steam and working an engine with a flash boiler depends for its success on the maintenance of a precise balance in the relations of the various phenomena. However, it is fair to say that this balance is so often secured that this type of boiler enjoys great favour with those who



Figs. 34 and 35.—Elevation and Cross Section of Serpollet Boiler.

thoroughly understand it; and, apparently complicated as is the Serpollet modern car, it is to such a large extent automatic that it is driven without difficulty after mastering the principles of its operation.

The English Serpollet flash boiler is shown in general view by Fig. 33, p. 61, whilst the Gardner-Serpollet boiler, a practically identical device, is shown in elevation by Fig. 34, and in cross section by Fig. 35, p. 63. It is built up with a number of horizontal sections of solid-drawn steel, as shown in Figs. 36 and 37, enclosed in an asbestos-lined casing, through which the ends of the sections project. Short connections, as illustrated, couple up the tubes externally, so that there is one passage from end to end, all joints being made steam-tight by copper-covered asbestos washers. The section, Fig. 35, corresponds to Fig. 34. Water enters at the top, is given a preliminary heating in the top tube, carried down to the feed-water heater, which is a square coil (Figs. 38 and 39) immediately above the burner, and then passes upwards through the sections; at about halfway a long external tube takes it to the top section but one, and from that it travels down again until it issues as superheated steam from the middle section. The circulation is shown by the arrows in Figs. 34 and 35. This is a new type, but in a still newer one the ends of the tubes are brought up to the top of the boiler. The connections are identical with those of the earlier form, but all external piping is covered in to prevent loss of heat, this improvement being said to give an improvement in steaming capacity of



Figs. 36 and 37.—Tubular Sections of Serpollet Boiler.

15 per cent. Four sizes of boilers are made, and all are tested to a pressure of 126·5 kg. per cm². (1,800 lb. per sq. in.), the ordinary working pressure is 21 kg. per cm². (300 lb. per sq. in.), and the maximum possible pressure in use is twice this. The arrangement of flues is shown in Fig. 40; the combustion products pass out at the top as indicated, and are then carried both upward and downward, thus down draught cannot affect the outward flow of the gases.

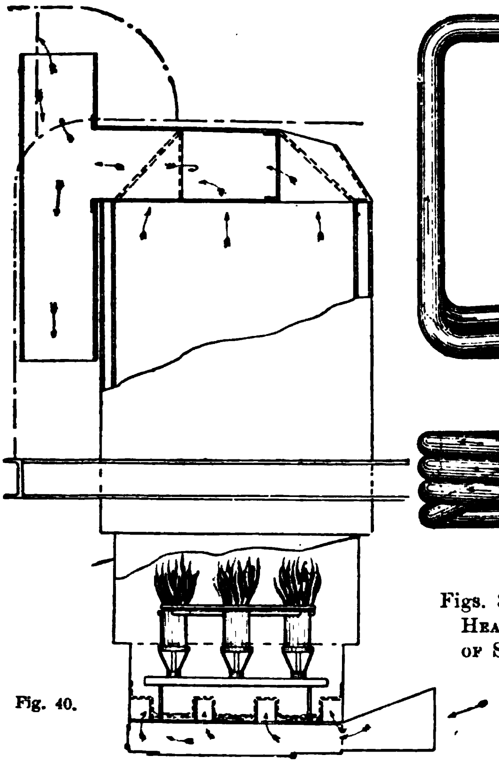


Fig. 40.

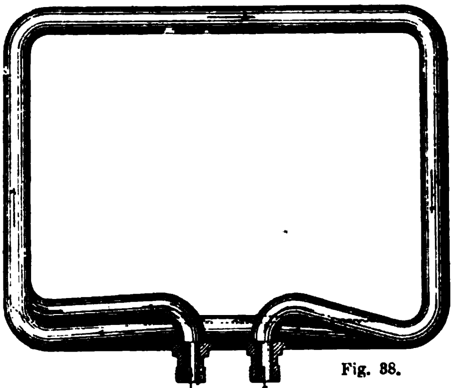


Fig. 38.

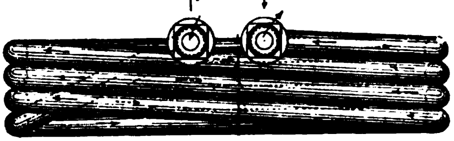


Fig. 39.

Figs. 38 and 39.—Serpollet Feed-water Heater. Fig. 40.—Burner and Flues of Serpollet Boiler.

The burner is represented merely diagrammatically in Fig. 40. A general view of it is presented by Fig. 41. It fits immediately beneath the boiler, and is fed with ordinary paraffin oil through the pipe shown in Fig. 41 projecting to the right, the feed pipe forming a rectangular coil round the top of the burner and acting as a vaporising tube. It feeds into a receptacle formed in the main casting, where is a wire gauze screen to keep back mechanical impurities; from this small horizontal passages communicate with each of the twelve or sixteen burners. These passages are bored right through the casting and are plugged by small outside screw-caps, A, on the removal of which it is an easy matter to clean out the passages at any time. Each burner nozzle—one is shown separately by B, Fig. 41—fits into a socket formed in the casting. The devices shown in Fig. 40 at the bottom of the burner nozzles, and shown separately by C, Fig. 41, are for the purpose of forcing them against copper-covered asbestos washers which complete the joints between the nozzles and the passages in the casting. The rectangular vaporising coil is supported by chimney-like devices, D, Fig. 41, fitting into the outside burner nozzle jointing devices just mentioned; both coil and chimneys form the necessary baffle and shield for the flames produced by the vaporised oil issuing from the nozzles. The air supply is indicated by arrows at the bottom of Fig. 40; it passes through perforated copper baffles, which distribute the draught. An air scoop makes possible an extra supply of air, and produces a forced draught when the car is in motion. The burner is started by heating the vaporising coil by burning methylated spirits in a pan below. The 6 h.-p. burner has 12 nozzles and the 12 h.-p. burner 16 nozzles.

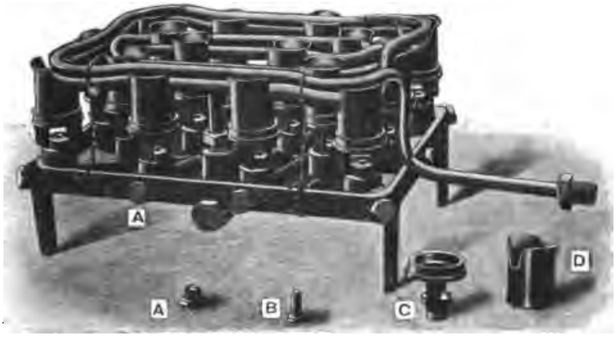


Fig. 41.—SERPOLLET BURNER.

The Gardner-Serpollet fuel and water connections are described fully in the chapter on steam cars (pp. 556 to 562), and there also will be found an explanation of the working of the special relief valve.

The Simpson and Bodman flash boiler is illustrated by Figs. 42 to 44, in which A is the casing, B the firebrick lining, C the fire bars, D the fire doors, E the boiler tubes, F the steel drum; the coupling nut and the coupling U-tube are shown on the right of Fig. 43.

There is an inner and outer funnel and a back pressure valve; L is the steam outlet. The boiler has six single bent tubes or twelve elements joined up in series and placed on a suitable casing. The boiler is started by a hand-worked pump, and is fed by a pump driven by a cam on the road wheel. An essential adjunct is the weldless steel cylinder shown in Fig. 43, which modifies the otherwise excessive amount of superheat possessed by the steam as generated. The working steam pressure is from 7 kg. to 15·8 kg. per cm.^{2} (100 lb. to 250 lb. per sq. in.), that is, its temperature ranges from 171° to 190° C. (340° to 390° F.); but the temperature of tubes usually is from 371° to 537·7° C. (600° to 1,000° F.), and consequently there is a considerable amount of superheat. The steam as generated is led into the steel drum, and in this is a bent tube or **U**-tube (*see* Fig. 43) through which passes the feed water, either direct from the feed pumps or after it has passed through one or two rows of tubes directly below the flue to cool the gases. The boiler now being very hot and ready for work, water is pumped by hand through the top rows of the tube, and probably passes through the **U**-tube in the drum as steam, thence to the bottom and highest row of tubes; it issues from the middle row as highly superheated steam to collect in the body of the drum, where it comes in contact with the **U**-tube and imparts some of its excessive heat to the contents of the latter. The weight of the generator is 292·5 kg. (645 lb.), and that of the steel cylinder 44·45 kg. (98 lb.), total 337 kg. (743 lb.).

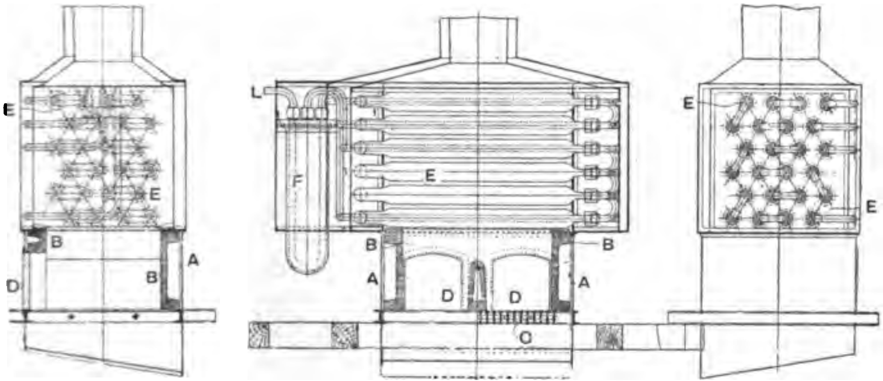


Fig. 42. Fig. 43. Fig. 44.

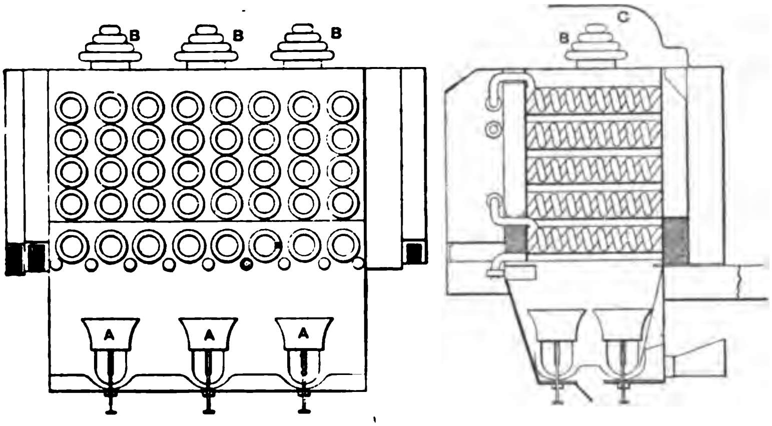
Figs. 42 to 44.—Simpson and Bodman Boiler.

The Musker boiler is stated to contain about 82·3 m. (270 ft.)

of solid-drawn weldless steel piping, 15·9 mm. ($\frac{5}{8}$ in.) bore, made into three concentric coils; the two centre coils are made with the rings slightly apart for the flame or heat to pass through, whilst the outer has the rings coiled closely together to prevent the heat escaping except at the end, and the outside is lagged with asbestos sheets and sheet iron. The ends of the two inner coils are stopped with asbestos, and the heat passes from the burner, which is attached to the outer coil, between and around the rings of the two inner coils, along between the outer and middle coils, and out at the end farthest away from the burner. The coils are joined together by steel unions at the back of the boiler. Water is pumped into the outer coil at the back farthest from the burner, and in its passage through the whole length is turned into saturated steam, and finally before leaving into superheated steam. It is said that there is no deposit or scale inside the tubes, because the rapid rush of steam has a scouring action, and because the rings of the coils are always altering slightly in form owing to the changes of pressure and temperature. The exhaust steam from the motor is passed into the flue at the back of the boiler, is superheated by the waste heat, and the gases and the steam pass invisibly to the atmosphere, the flue outlet being near the ground.

The oil burner for heating the Musker boiler is of cast-iron. A fan forces air at a pressure of 25 mm. (1 in.) of water through the heating chamber, which is heated by the flame, and then through a port into the oil-vaporising chamber, into which oil is pumped through a pipe of 4·8 mm. ($\frac{3}{16}$ in.) bore. The heated air takes up the vaporised oil, and mixture is perfected by passing it backwards and forwards around the burner; finally it passes through the centre to the nozzle, which consists of a cast-iron disc 5 cm. (2 in.) thick, having in it about 120 holes each of 9·5 mm. ($\frac{3}{8}$ in.) diameter, at the back being a 6·3 mm. ($\frac{1}{4}$ in.) plate also perforated, which fastens a disc of gauze wire over the holes to prevent back-firing. Through the centre of the burner is fitted a wrought-iron pipe 38 mm. ($1\frac{1}{2}$ in.) in diameter, to allow a lighted taper to be placed in front of the nozzle from the outside of the burner at starting. A grid in front of the nozzle steadies the flame and deflects some of the heat to the walls of the heating chamber. There is no smell with this burner, and it can be made quite noiseless. The consumption of fuel (any kind of refined or crude oil) is 976 kg. per m.^{2} (200 lb. per sq. ft.) of nozzle or grate area.

The Chaboche is a rectangular flash boiler carried at the rear of the car, and two sectional views of it are shown by Figs. 45 and 46. The 12 h.-p. boiler has five separate lengths of weldless steel tubing; through a tubular grid at the bottom, somewhat resembling a Gardner-Serpollet boiler section, the water first passes. The coiled tubes, wound to resemble a helical spring, are bent backwards and forwards so that the convolutions lie close up to one another in the same horizontal plane. The lowest of the five coiled sections is in halves for easy removal of either half when necessary. One layer lies across the underneath one with its coils at right angles to it; this is effected by alternate layers having five long coils and a correspondingly greater number of short coils. The bottom tubular grid forms the feed-water heater, and from it the water passes first to the top coil—the steam generator—and thence to the lower coils—the superheater. Thence it passes through a safety valve and throttle valve to the motor, the steam pipe acting as a thermostat for automatically controlling the burner according to the steam temperature. (With expansion, due to increased temperature, it closes a needle valve on the fuel supply pipe.) The coils are connected together at the back outside the actual generator but inside the casing, the ends of the tubes being flanged over and the faces of the flanges being forced together with unions, no packing being used. The burner A is fixed beneath the boiler, and its flames pass up through the coils.



Figs. 45 and 46.—Chaboche Flash Boiler.

the burnt gases escaping through chimney B, fixed on a removable portion of the boiler casing; a big reflector plate, C, covering all the chimneys, prevents the hot gases from getting into the body of the car. Water and fuel are fed mechanically, and the feed water is regulated automatically; so is the fuel feed, as noted above (*see* also pp. 562-564).

The Chaboche burner uses ordinary paraffin, and consists of six actual burners, A, Figs. 45 and 46, of one of which a section is shown by Fig. 47. The paraffin is led, through the vaporising tube shown, to M, and thence to nozzle A, and the coil is heated preliminarily by burning methylated spirit. A deflecting cone, B, above the nozzle spreads out the flame and keeps the coiled tube vaporiser hot. The only place in the nozzle where dirt could interrupt the flow of the oil is where the oil issues through the fine hole at the top, and a needle, C, can be forced up to clear any obstruction there, and then moved down again out of the way. The burner nozzles being in two rows of three each, either row can be used separately; the front set is fed through the left-hand hole in fitting D, which passes accoss the back of the burner casing, and the other set is fed through the right-hand hole. The flow of oil to the two passages through the fitting D is controlled independently by a distribution valve fixed near to it at the back of the car.

The Blaxton flash boiler (Fig. 48) presents some novel and interesting features. It consists of a number of superimposed coils of steel tubing bore, 25 mm. (1 in.), each coil forming a separate element, and having about ·9 m.^{2} (10 sq. ft.) of heating surface. The coils are joined up in series, with nuts and unions placed outside the case and away from the heat. The principal feature is the means for adjusting the supply of liquid fuel in the same ratio as the steam consumption. The oil is forced under air pressure through a heating coil, where it is vaporised, and thence to the burner, which has a perforated cap capable of slight vertical motion; to the cap is attached the spindle or stem of the needle valve. Rigidly fixed in the vertical axis of the boiler is a large tube, closed at its lower end, which just touches, or nearly touches, the burner cap. At the top the tube is connected to one of the elements, and within the tube is another open at its lower end, and also connected to an element, thus providing a path for the continuous circulation of the steam or water. The action is as follows: On lighting the burner the temperature of the elements is raised sufficiently to vaporise the feed water, and if there is a constant supply of cold water the central tube remains at a certain temperature, and consequently its length (dependent on expansion and contraction) allows the needle valve in the burner to pass sufficient oil gas necessary to vaporise the water. Diminishing the feed causes the central tube to get hotter, and its lower end presses upon the top of the needle-valve spindle, and the supply of oil gas is lessened. The boiler illustrated is 1·75 m. × ·91 m. × ·91 m. (5 ft. 9 in. × 3 ft. × 3 ft.); it has 11·7 m.^{2} (126 sq. ft.) of heating surface; the normal steam pressure is 14 kg. per cm.^{2} (200 lb. per sq. in.); it will supply a 25 h.-p. motor; and its weight, including casing and fittings, is about 700 kg. (14 cwt.) In Fig. 48, A shows

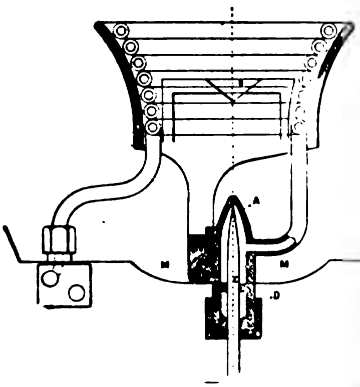


Fig. 47.—Chaboche Paraffin Burner.

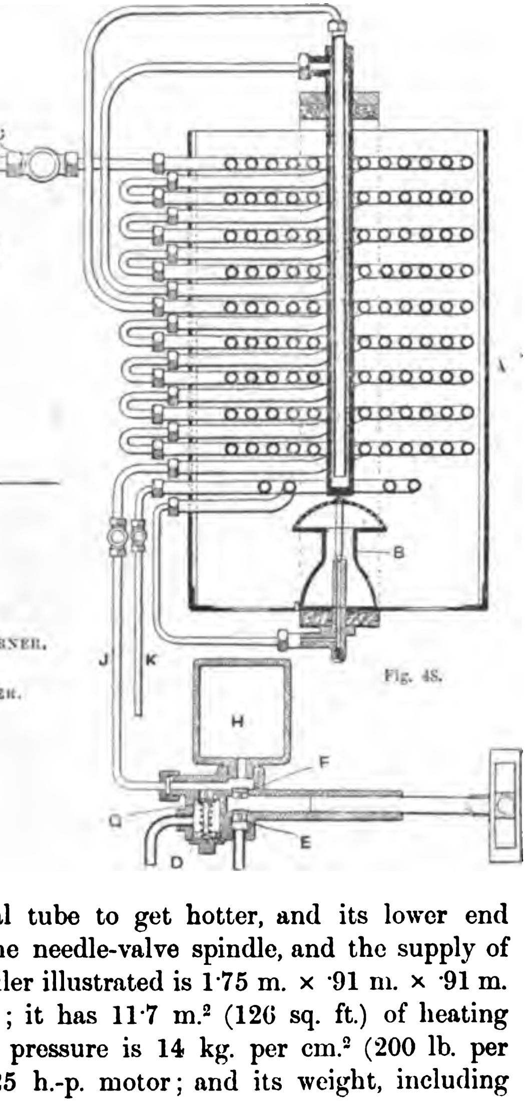


Fig. 48.—Blaxton Flash Boiler.

the boiler, B the burner, C the steam valve, D the water pump, E the suction valve, H the air-vessel, J the water supply pipe, and K the oil supply pipe. The oil pump is of the same design as the water pump illustrated.

The White tubular flash boiler has distinctive features, and indeed is, unique. It is composed of coiled steel tubes, some of

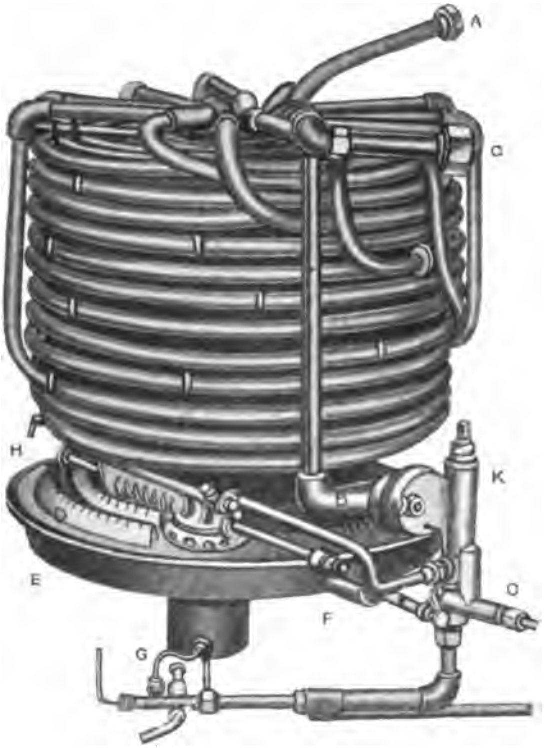
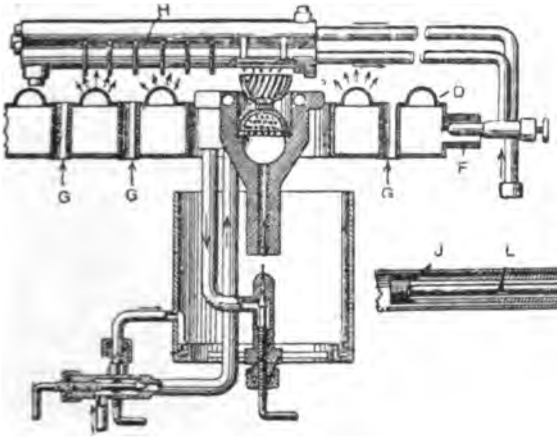


Fig. 49.—White Semi-flash Boiler.

which contain water at all times, and it is thus capable of supplying steam for restarting after the car has stood for some time. Its chief advantages are this capacity for storing energy and the fact that steam generation need not correspond instantaneously with the supply taken by the motor. These advantages are obtained by connecting each layer of coils with its neighbour through pipes which rise above the boiler, so that although the water is fed into the top coil first, it cannot flow down to the bottom coil until it first has filled completely each successive coil. The upper tubes, naturally receiving less heat than the lower ones, may be regarded as the feed-water heater, the lower ones being the superheater. The water and fuel feeds are independent, different from the Serpollet system. The heat of the burner is hand regulated, and the driver shuts off the main fuel feed to the burner when the car is stopped; the upper coils of the burner then still contain water, and are in open communication with the throttle valve. On again turning on the fuel, the water is evaporated and the car restarted, there not being any necessity for forcing water into the boiler or using an automatic self-starter as in the Serpollet system. For this reason the White boiler is termed by its maker a "semi-flash" boiler. A brief description of the construction is here given. Fig. 49 is a general view of the boiler and special burner. The boiler consists of twelve horizontal coils of solid-drawn steel tube of 6·34 mm. (0·25 in.) bore. Water enters the top coil by pipe A, and having filled it, flows through one of the connecting pipes shown on top into the second coil. Each successive coil is connected in the same way, the whole of the connections being above the coils. The further end of the bottom coil is connected with a pipe passing across the burner beneath the boiler and enclosing a thermostat. Through this tube passes the steam, which then is led through the vertical pipe B to



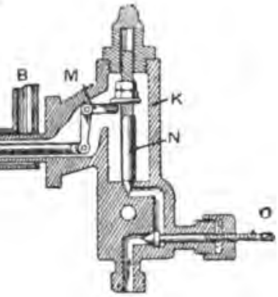


Fig. 50.—White Pilot Lamp. Fig. 51.—White Thermostat Automatic Fuel Regulator.

the top of the boiler; the steam goes to the throttle valve from the union connection, C. The coils are held together by U-shaped stays, one end of which passes up the centre of the boiler and the other end outside. These are used to clip the boiler in place in the car, and are held together by top tie bars. The coils are enclosed in a case of sheet iron and asbestos. The average working pressure is about 17·5 kg. per $cm.^2$ (250 lb. per sq. in.), and the safety valve is set to blow off at double that pressure.

The White burner and its connections are of special interest. Its main portion D (Fig. 49) is a casting whose upper surface is formed into circular ridges with a large number of slits across them. The ridges communicate with an open space formed inside the burner between the casting D and a stamped metal pan E, the edges of which are lapped over the edge of the casting. Vaporised petrol spirit mixed with air is injected through the cone F into the main body of the burner, and issues from the slits already referred to. Auxiliary air from beneath passes through the tubular passages, G Fig. 50 (which shows part of the burner and a section of the pilot lamp) and assists combustion, but is not mixed previously with the gas inside the burner itself. The vaporiser H is heated by the burner itself when that is alight, but it has a plate fixed to it immediately above the pilot lamp, and normally is heated from that source. The thermostat J is carried by the casting K, which encloses the needle valve controlling the feed of fuel to the vaporiser. The thermostat passes diagonally across above the burner; it consists of a brass tube J (Fig. 51) enclosing a steel rod L, connected through a bell crank M with the needle N. When the temperature of the steam passing around the tube J reaches a certain point, its expansion causes the rod L to be drawn away from the fitting K, and the bell crank allows the needle N to reduce the petrol feed flowing past it. This valve very nearly, but not quite, closes. Although the driver can regulate the petrol feed to the burner by the valve O, it is left fully open in ordinary practice when the car is travelling. The nozzle from which the gas issues into the burner is also fitted with a needle valve, but its object is more that of cleaning the orifice when necessary than for regulating the passage of gas. The fuel and water connections on the White car are further dealt with on pp. 570 and 571.

The type of Nègre boiler (Fig. 52) used for light cars may have a powerful Longuemare burner, consuming about 1 l. (1·76 pt.) of petroleum to vaporise sufficient water to produce one horse-power hour, or it may be fired with alcohol, coke, or coal. The feed water enters from below, and is heated in a bundle of tubes, all of which communicate with an annular chamber; these tubes have a bore of 6 mm. (·236 in.) and an outside diameter of 12 mm. (·472 in.), and they number 204. Vaporisation begins instantly the burner or fire is lit. Each tube is connected to a collector above by a very small passage, which obliges the water to separate from the steam, the circulation being very slow. The dry steam passes to a second collector below the first, connection from one to the other being assured by U-shaped tubes, as shown in Fig. 52. The steam passes through a hollow bolt, which at the same time serves to hold the steam pipe. Thus the steam becomes superheated and, though under a low pressure, is still very dry.

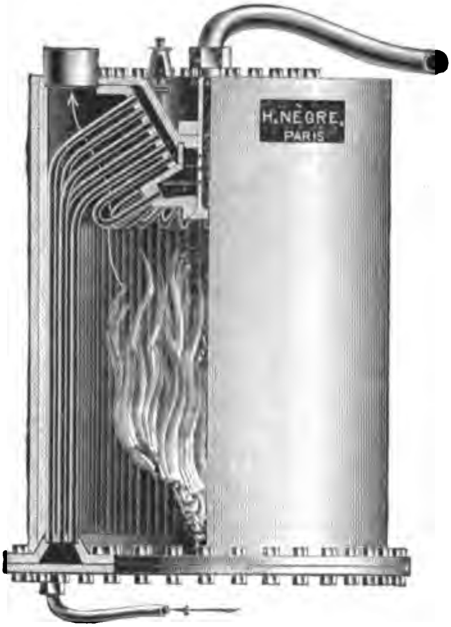


Fig. 52.—Nègre Boiler for Light Vehicles.

Valentin boilers are so named from their designer, manager of the workshops of the Compagnie Générale des Automobiles, who also runs the water to be vaporised into the very small annular space between two concentric iron tubes, but the flames reach the inside of the small tube as well as the outside of the large, thus increasing the heating surface. Water is injected by a pump. There is no needle valve, as in the primitive Serpollet type. The fuel employed for heating is coke, which slides automatically on an inclined grate, and the draught is obtained by a very short flue, the fire-box being in front, and the motion of the car gives a sufficient draught. The exhaust steam is not injected; instead it is condensed by running it through a system of tubes with gills, and these gills, instead of being cast on with the tubes, are forced on them.

The principle of the Montier and Gillet boiler is similar to that of the preceding. The flames ascend between the horizontal tubes, then descend along the ends of these tubes opposite the flue, and cross them horizontally to reach this flue. The steam formed passes into collectors, where it is dried, as is necessary after such rapid vaporisation.

In the Kécheur boiler each part is formed, first by a vertical steel tube, and inside that a thicker steel tube fits exactly; the inner tube has, on the part near the outer tube, a helicoidal square groove, 15 mm. (0·59 in.) in section. It is heated by a Longuemare petrol spirit burner similar to that employed for heating the incandescent ignition tubes of petrol motors. The flame from the burner enters into the flue formed by the interior tube, and there causes a draught and very active combustion. The parts are united together by horizontal sleeves, with joints well secured by a double screw-thread running in opposite directions, so that the water and steam pass along the complete circuit. Feeding is accomplished by an automatic pump, whose delivery can be regulated with a lever so as to vary the speed of the car, there being no mechanical change of speed. The water injected is obtained largely from exhaust steam condensed in an appliance in which use is made of the absorbing power of wire gauze. The Toward and Philipson, and Tangye and Johnson boilers may be mentioned by way of note.

Such are the most commonly employed boilers for automobiles. Vertical fire-tube boilers, formerly used only on heavy vehicles such as the Leyland and Coulthard, are now used on light cars, such as the House, Chelmsford, Locomobile, etc. As a rule water-tube boilers are suitable only for heavy vehicles, but the Toledo light car finds a special type satisfactory. Their weight (500 kg., or 1,100 lb.) is the reason, the amount of water they contain (about 50 kg., or 110 lb.) being sufficient to cause risk of explosion (mere bursting of a tube may have serious consequences), but not enough to ensure regularity of pressure and level. It is regrettable that their tubes have not gills, for it must not be forgotten that Baudry demonstrated on the locomotives of the Paris-Lyons-Mediterranean Railway that where gilled tubes vaporise 92 kg. (202 lb.) of water, smooth tubes vaporise only 75 kg. (165 lb.); and the relative proportion is the same in the case of automobiles. It may be added that boilers with hanging tubes seem to start more rapidly than others. Both light and heavy cars can have flash boilers, but only exceptionally are such heavy cars heated by liquid fuel; flash boilers fed with proper proportions of water and petroleum, as in the Serpollet, seem capable of doing good service.

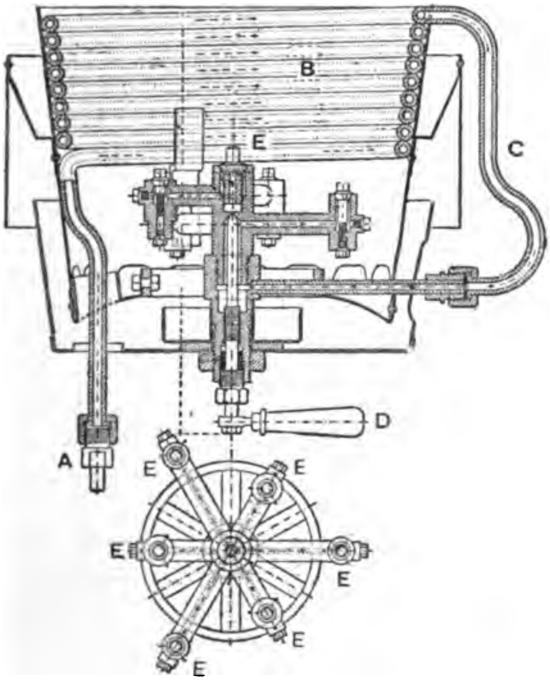


Fig. 53.—Longuemare Burner for Boilers.

The burners employed with liquid fuel under automobile boilers are very variable in form, but are mostly based on the principle of the Bunsen burner; that is, the pressure at which the gas or vapour is supplied to the burner causes the drawing in of most of the air requisite for combustion. For automobiles generally recourse is had to air under pressure forced by a pump into a receptacle containing petroleum. The vapour from the petroleum has to be obtained at the outset by small temporary burners easily ignited with a little alcohol, and heating the closed vessel containing a certain amount of liquid fuel. The live steam, also, can be employed to draw in the fuel and air. Heating with liquid fuel has incontestable advantages, and enables steam to be got up more rapidly than with coke or coal.

Burners already described are the Clarkson and Capel, Lifu, Weston, Serpollet, Musker, Chaboche, Blaxton, and White.

The Longuemare burner for petroleum (Fig. 53) is used on many vehicles, and is of exceptional power. The oil enters by the vertical tube A, and is vaporised in the steel worms B, on arriving at the top of which the vapour is conducted by the pipe C to the base, where is situated a central screw valve regulated by the handle D, to control the supply. There are seven burner tips, E, as illustrated in plan in the type here dealt with, but smaller burners have only one or some number less than seven, Fig. 53 illustrating the most powerful Longuemare burner made (No. 4), its maximum consumption of oil being between 6 l. and 8 l. (10·5 to 14 pts.) per hour. The supply to each burner tip can be regulated to a nicety, and when the vehicle is proceeding at half-speed only three burner tips need be kept alight, and the four others are cut out The present burner is a development of simpler and less powerful devices. No. 1 burner consumes about 2 l. (3·5 pts.) of oil per hour; No. 2, 4 l. (7 pts.) per hour; No. 3, from 4 l. to 5 l. (7 to 8·8 pts.) per hour; 1 l. (1·76 pt.) gives the 1 h.-p. hour.

The Creek or Cremorne steam van employs in connection with a flash boiler an ingenious fuel and water regulator and a Johnston burner. Fig. 54 is a section of the regulator, the regulating rod O in which is attached to the lever F of the burner shown in elevation by Fig. 55 and in section by Fig. 56. The regulator has a reservoir A (Fig. 54) containing air under a pressure equivalent to that in the boiler. Water from the feed pump enters pipe B, and through C reaches cylinder D. A portion of the water enters the reservoir A through the annular space C^1, and rising to the top of tube E flows down that tube to the passage F, where it is held by the relief valve G. The two opposite pressures operating the regulator are (1) that of the boiler acting on the under side of piston H, and (2) the feed pressure acting upon the top side of the piston. Pipe I and passage I^1 convey the pressure to the bottom of the cylinder, and also are in connection with a relief valve, J. The piston rod K has a long conical valve, K^1, turned on its lower end, which comes in contact with its seat L in the cylinder cover when the piston is at its highest point. Connected

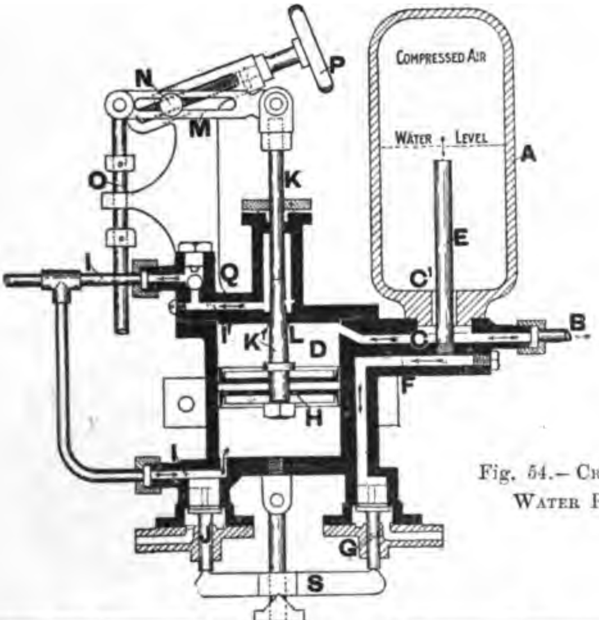
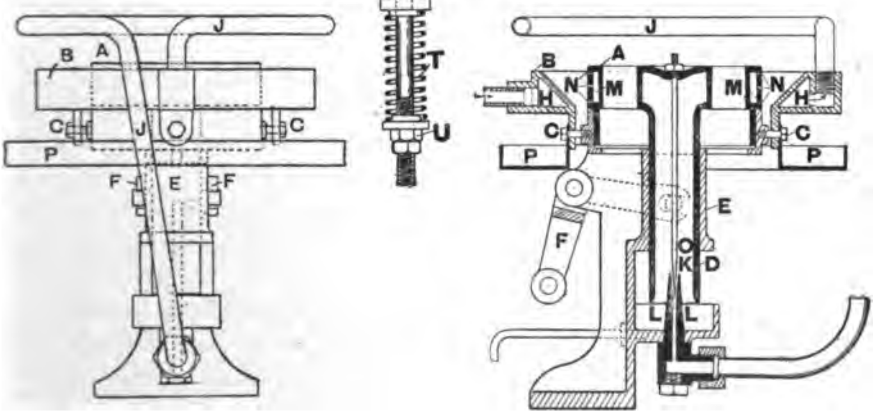


Fig. 54.—Creek Fuel and Water Regulator.



Figs. 55 and 56.—Creek or Johnston Paraffin Burner.

to the top of the piston rod K is a lever, M, acting at its other end and connected to a rod, O, which controls the paraffin feed by raising or lowering the burner. M is fulcrumed on N, whose lateral position, which determines the vertical play of rod O, is adjustable by means of the hand wheel P; the stroke of rod O is altered in proportion to that of the piston rod K. Suppose the fulcrum N to be adjusted to maintain a constant head of steam at, say, 14 kg. per cm.^{2} (200 lb. per sq. in.), with a like pressure in the reservoir A. The boiler pressure under piston H tends to force it up and cut off the water supply by means of the conical piston rod K^1. The feed-pump pressure above piston H counterbalances this tendency, however; but should the boiler pressure exceed the feed pressure, the piston H rises and decreases the water supply, and the fuel valve cuts down the supply of paraffin. The reverse is the case if the feed-water pressure exceeds the boiler pressure, more water passing into the boiler through the ball check valve Q and pipe I. The relief valves G and J act as safety valves to the boiler and feed-water supply, and are held on their seats by beam S and spring T, regulated by nut U.

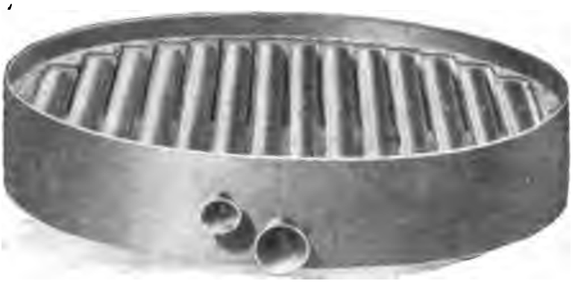


Fig. 57.—PRESCOTT BURNER.

The paraffin burner (Figs. 55 and 56) used in connection with the above regulator has two concentric rings, A B, fastened together by bolts C. The inner ring A carrries a sleeve, D, which slides in the bracket E, and so the inner ring—the actual burner—can be raised or lowered by means of the forked lever F. The oil fuel enters the outer ring B through the pipe shown at the left-hand side, and is heated in the annular space H and vaporised in pipe J, which is in contact with a portion of the flame. The vapour is ejected at the nozzle K, and mixed with air which enter at L. The mixture passes into the annular chamber M of the burner A, and is ignited at a number of small holes, N. When the regulator described above raises the burner bodily, needle valve O is lifted from nozzle K, and allows a large amount of oil vapour to pass to the burner; also, the flame is brought nearer to the vaporising tube J, and greater heat obtained to vaporise the larger quantity of oil passing. For starting, oil is burnt in tray P.

The Prescott (American) burner (see Fig. 57) has fourteen parallel tubes, with air spaces between, within a cylindrical case. Connecting all these together is a transverse pipe, into which is injected the combustible mixture through the lower of the two cones shown in Fig. 57. The injection apparatus, a diaphragm valve, is shown in Fig. 58. A separate jet feeds petrol vapour into the upper and smaller cone whose passage leads nearly half-way through one of the tubes forming the burner, this particular tube being stopped off internally at this point, and forming the pilot light. The combustible mixture issues from the two rows of holes in the upper sides of the tubes, as in Fig. 57, to feed the furnace. The main fuel-feed leads to the diaphragm fitting, Fig. 58, the petrol passing through a coil placed above the boiler and leading through two of the boiler tubes before being led across above the burner to this fitting. The main burner feed is controlled automatically by the steam pressure in the diaphragm valve in much the usual manner, a needle valve regulating the flow of fuel. The diaphragm does not control the auxiliary feed to the pilot light, which can be cut off by the hand wheel shown to the left in Fig. 58, or the quantity passing to the burner can be regulated by another needle valve. At starting, a blow-lamp heats the external pipe fittings immediately outside the pilot light feed. This vaporises sufficient oil for the pilot light, and steam can be raised in about six minutes.

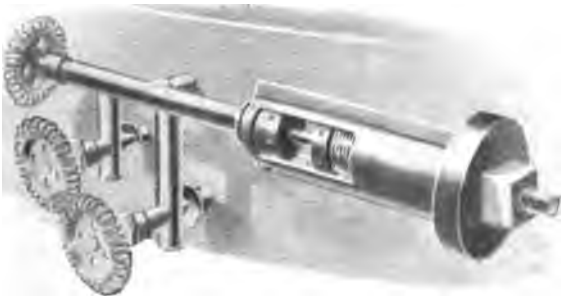


Fig. 58.—PRESCOTT DIAPHRAGM VALVE.

CHAPTER IV.

STEAM MOTORS FOR AUTOMOBILES.

THE steam engine, or, in automobile language, the steam motor, is naturally suitable for automobile service; and the opposite to what was the case with the steam boiler, it was not necessary to alter it much to adapt it to its new application. Already possessing the essentials of an automobile motor—simplicity, reliability, elasticity, and, apart from the boiler, lightness—it was adopted just as it was, and, it may almost be said, under all the various forms the steam engine is capable of assuming. For though, as yet, practical results have been given only by the alternating type with fixed cylinders and single or double expansion, both the oscillating and rotary types have been tested for automobile service. Consequently, in the review about to be given of the various applications, the methodic order of a regular classification of steam motors can be followed.

Simple expansion alternating motors, with oscillating cylinders, will be considered first. The Ravel motor, employed for the tricycle of 1868, had two oscillating cylinders working at about 100 revolutions per minute, so that the cranks could be coupled directly with the driving axle, because at this rate the engine was considered to be able to withstand the effect of the jolts caused by the road. This system was not imitated, probably because it was too destructive to the mechanism, in spite of the elastic working of the motor, a tangible proof of which is given by the railway locomotive, and the fear of jolts on the road caused the speed rate to be kept too low. This is to be regretted, because, dispensing with toothed or other transmission gear with several speeds, this device gave a simplicity not to be found in others. Moreover, if instead of a two-cylinder motor, driving the same axle, two independent cylinder motors are employed, each driving a wheel, there is no necessity for that always complicated part, the differential. Some day, perhaps, an ingenious invention—for example, that of a spring capable of sufficiently deadening the jolt caused by the road—may enable the above system to be returned to.

The Amédée Bollée motor was an example of the simple expansion alternating motors with two fixed cylinders inclined at 45°. This motor had a balanced rotary distributor, allowing expansion and reversing. With the boiler described on p. 46, two cylinders, 0·15 m. (5·9 in.) in diameter and 0·16 m. (6·3 in.) stroke, gave an average of 15 h.p., which could be increased to 30. The Serpollet (first type), Le Blant, Scotte, and Weidknecht motors are of practically the same type as the above, except that they have two parallel cylinders.

The Le Blant motor has two parallel cylinders, each 170 mm. (6·7 in.) diameter and 180 mm. (7 in.) stroke, and the admission of steam is governed by cylindrical balanced slide valves variable from 10 per cent. to 80 per cent. by a Walschaërt's valve gear, which has the advantage of not employing an eccentric and of working in all notches of expansion without altering the lead of the slide valves, whereas the Stephenson link motion decreases the lead and admission near the dead centre. This motor, weighing 450 kg. (990 lb.), gives an average of from 15 to 20 h.p., and can attain 30 h.p., and generally rotates at a speed of from 180 to 200 revolutions per minute. The motor of 20 to 30 h.p., capable of giving 60 h.p. exceptionally, has two cylinders of 200 mm. (7·8 in.) diameter and 220 mm. (8·65 in.) stroke, and weighs 900 kg. (1,980 lb.).

Weidknecht employed for his omnibus with 15 seats, and carrying 500 kg. (1,100 lb.) of luggage, a 20 h.p. motor with cylinders 125 mm. (4·9 in.) in diameter, and the same stroke, Solms' system of radial expansion not employing link motion, and giving a variable expansion with wide limits (10 per cent. to 83 per cent.). Normally, the engine worked at 350 revolutions per minute.

Scotte employed the steam-hammer type of engine, with two double-acting vertical cylinders. The omnibus which figured at the heavy vehicle competition at Versailles in 1897 had a motor of 14 h.p., cylinders 110 mm. (4·3 in.) in diameter, and 115 mm. (4·5 in.) stroke. The valve and reversing gears consisted of the ordinary eccentrics and Stephenson's link motion, and admission could be prolonged for 70 per cent. of the stroke; the motor worked normally at the rate of 400 revolutions per minute, and weighed 270 kg. (594 lb.)

The steam-hammer type also was adopted by the Lancashire Steam Motor Company, whose engine is not reversible, by D. Martyn, and Freakley. In the Freakley motor for a car with 30 seats, each cylinder is 11·5 cm. (4·5 in.) in diameter, and 22 cm. (8·7 in.) stroke; distribution is by slide valve and Stephenson's link motion. In the Stanley motor for car with 2 seats, the pistons are 5 cm. (2 in.) diameter, and 9 cm. (3·5 in.) stroke.

The Chelmsford 12 h.p. steam motor (Clarkson and Capel), shown in vertical section by Figs. 58 and 59, has two horizontal double-acting high-pressure cylinders, with a bore and piston stroke of 10·2 cm. (4 in.). The pistons are shown at A. The crank chamber is entirely enclosed, and the countershaft differential gear is placed inside it. The slide valves B beneath the cylinders are operated by Joy valve gear enclosed in a casing, C. The crankshaft has two overhanging cranks, D, set at an angle of 90° to one another, and is carried in bearings E, formed in the casting F. The power is transmitted from a steel spur wheel G between the two cranks to a phosphor-bronze wheel surrounding the differential gear, the countershaft of which is mounted in four double ball bearings. The cross countershaft drives four separate pumps—the boiler feed-water pump, the lubricating oil circulation pump, con-

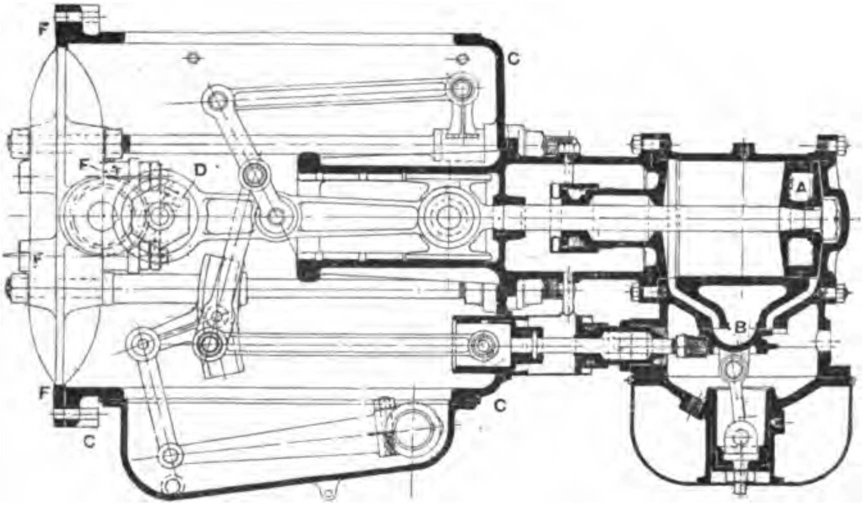


Fig. 58.—Vertical Section of Chelmsford Steam Motor.

dense water pump, and the paraffin oil feed pump. The countershaft chain drives the road wheels in the usual way. A separate pipe leads the exhaust from each cylinder through feed-water heaters to a cooler forming the front of a bonnet which is placed much as in a petrol car (see p. 549).

The Toledo 7½ h.p. steam motor (American) is shown in general view by Fig. 60, p. 86. It is pivoted to the car body by a ball joint at the top, and is also held in position by a distance rod passing to the back axle. It has two vertical cylinders, double acting and high pressure, and, instead of slide valves, it has piston valves as illustrated. These have rings to prevent leakage. The cylinder bore is 7·6 cm. (3 in.) and the piston stroke 10 2 cm. (4 in.). Cranks, eccentric blocks, and the central sprocket are drop forgings; the crank-shaft is carried in ring lubricator bearings, 2·8 cm. (1·125 in.) in diameter, and ball bearings are not used at all. The valves are operated by the usual link reversing gear. The valve stems are ball-jointed to the guide pieces which operate them. The crank chambers entirely enclose the connecting rods and cranks, which are lubricated on the splash principle, the connecting rods having scoops at their ends for throwing the oil on to the various parts.

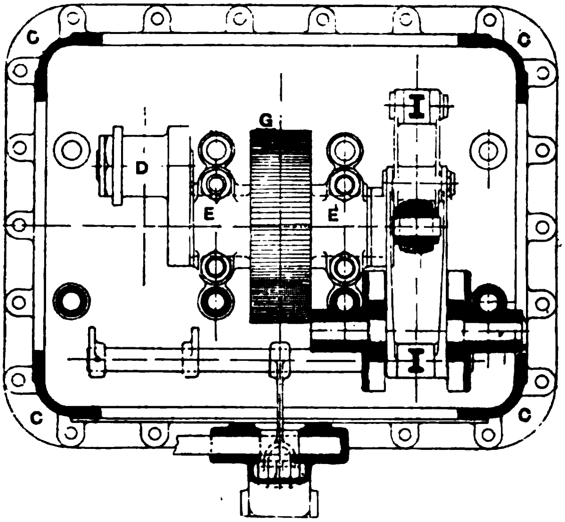


Fig. 59.—Vertical Section of Chelmsford Steam Motor.

The cylinders are lubricated automatically from a steam-pressure tank of a capacity sufficient for 240 km. (150 miles). The cross-heads for the two cylinders are connected with the plungers of two pumps fitted at the sides of the motor and enclosed in dust-proof casings. One pump is for the boiler feed water, and the other maintains an air pressure in the fuel tank. Relief cocks in the cylinders allow any condensed water to escape at starting. The makers claim that this motor produces one horse-power hour for every 10·9 kg. (24 lb.) of steam supplied by this boiler (see p. 57).

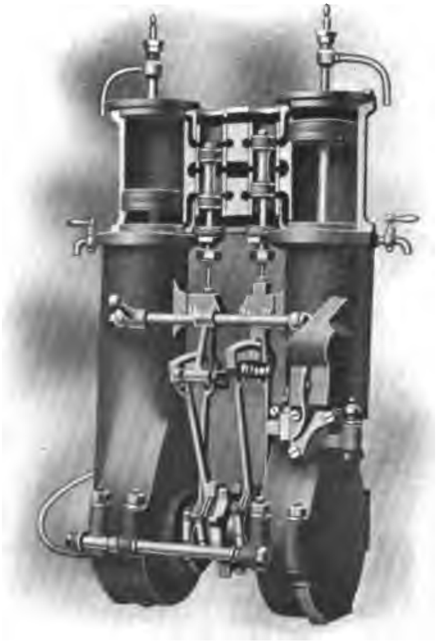


Fig. 60.

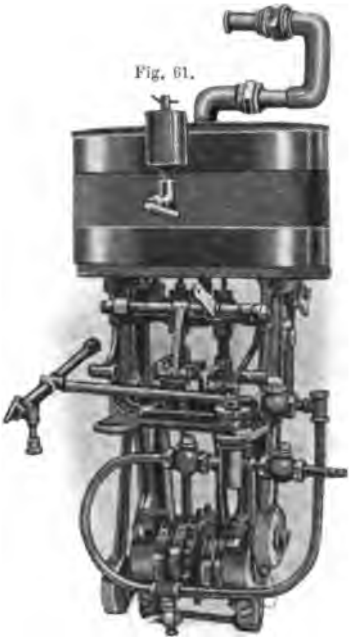


Fig. 61.

Fig. 60.—Toledo Steam Motor.
Fig. 61.—Weston Steam Motor.

The White steam motor (American) has two cylinders and is double-acting, not differing materially from the other American motors now becoming so popular. It has slide valves and the usual link motion reversing gear. The cylinder bore is 8·9 cm. (3·5 in.), and the piston stroke is 10·2 cm. (4 in.). The one novel feature is the aluminium crank chamber, entirely enclosing all moving parts between the cylinders and central driving sprocket. The crank chamber has a removable base on each side of the driving sprocket, thus rendering the ball bearings, which are employed throughout, very accessible. The left crosshead drives the feed-water pump, condense-water pump, and an air pump for maintaining pressure in the petrol tank. For lubricating the cylinder, a small pump is introduced into the oil tank; the pump plunger is connected with a rod controlled by the driver, who unscrews the rod to unlock the pump valves. Then the plunger can be worked by hand, and the lubricating oil injected into the live steam pipe, whence it is carried as spray into the working cylinders.

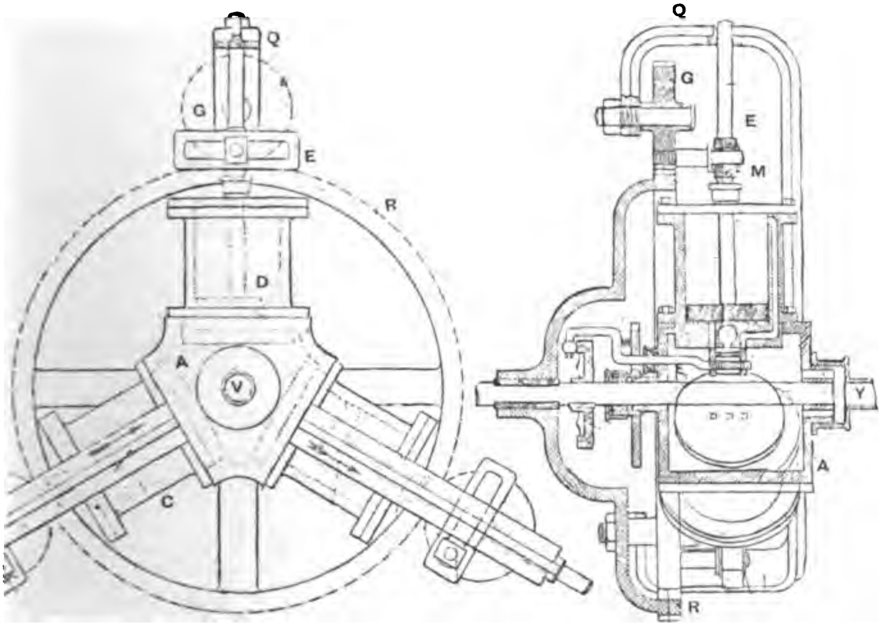


Fig. 62. Fig. 63.

Fig. 62.—Vertical Section of Kècheur Steam Motor. Fig. 63.—Section of Cylinder.

The Weston steam motor typifies American construction, and after what has been said it is not necessary to give a detailed description of it. Fig. 61 shows a 6 h.p. double-acting two-cylinder motor with the customary link motion. The frames are of phosphor-bronze, and the majority of the bearings are ball. The eccentrics and driving sprocket form a single drop forging, and the two cranks which fit into this piece at the ends are strongly pinned in place. This method supersedes the built-up shafts formerly employed.

The chief point of the House 10 h.p. horizontal steam motor is the means whereby a special controller underneath can put the two cylinders (ordinarily running, as it were, in series) in parallel for hill climbing, etc. This electrical simile is explained by saying that, on operating the controller, live steam is admitted from the boiler into both of the cylinders, which are then high-pressure (this being the parallel arrangement), instead of one cylinder being high-pressure and the other working with the low-pressure steam taken from the first (this being analogous to a series arrangement). Piston valves replace the ordinary slide valve. The motor is suspended from a bracket by means of a double ball-jointed rod.

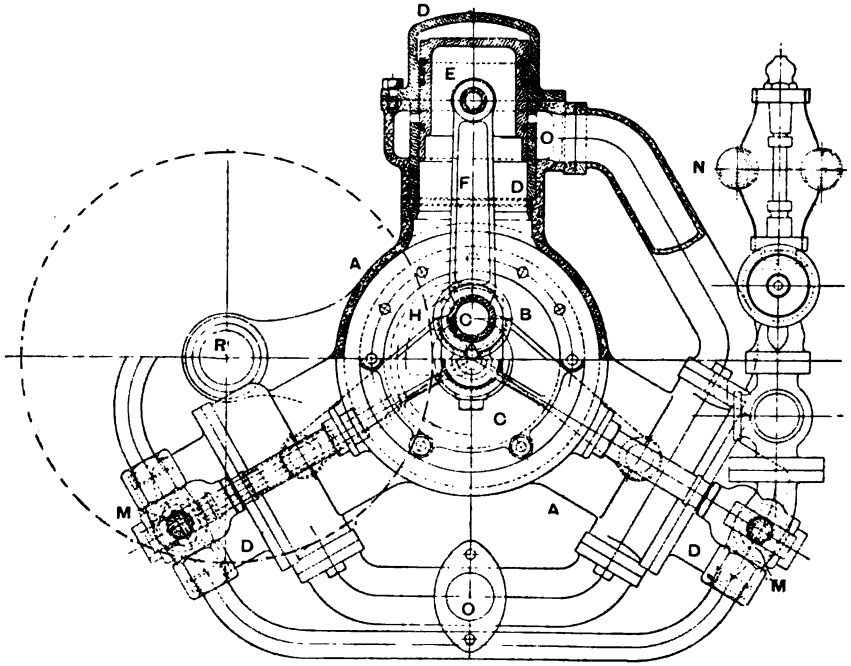


Fig. 64.—Simpson and Bodman Steam Motor: Transverse Section.

The Miesse nominal 10 h.p. steam motor, employed on a lurry, has three horizontal cylinders cast in one, and bolted to an enclosed crank chamber. The mushroom-type inlet valves on the upper side and the exhaust valves on the under side are all operated by cams, which with their shafts slide longitudinally in order to reverse. This is similar to the Serpollet system, as a glance at the view of the Serpollet motor, Fig. 69, p. 93, will show. The spur wheel fixed to the cam shafts also are drawn sideways in mesh with a wide spur wheel which drives them. The crank chamber encloses the differential gear, on the casing of which is a spur wheel driven by a pinion on the motor shaft. One end of this shaft operates an air pump, which maintains a pressure in the fuel tank, and at the other end an eccentric mounted on a small countershaft works the water pump.

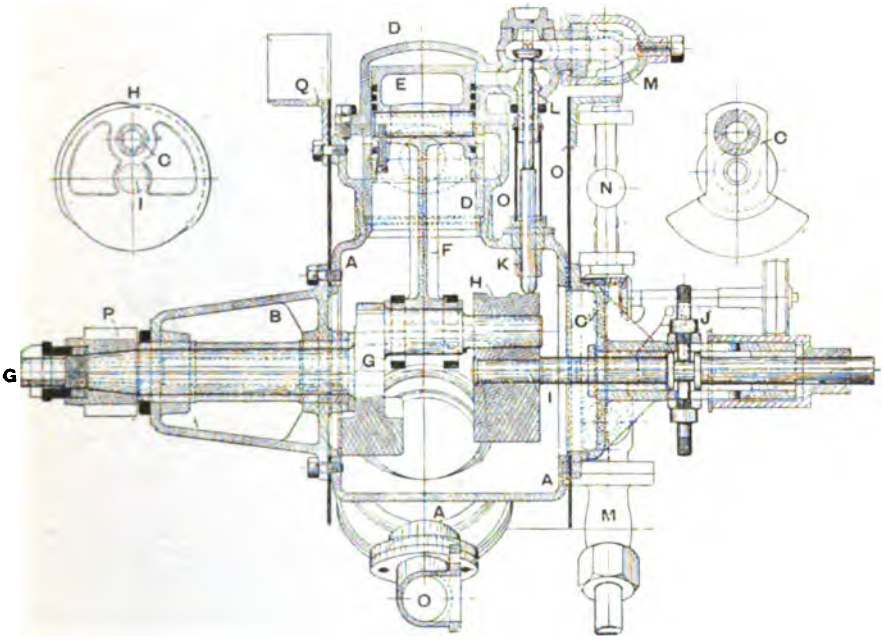


Fig. 65.—Simpson and Bodman Steam Motor : Longitudinal Section.

With regard to engines having three cylinders at 120° one to the other, the Kécheur motor (Figs. 62, 63, p. 87) has three double-acting cylinders radiating round a frame of triangular section A, which acts as a common steam-chest to them. Distribution is by three slide valves governed by a cam C keyed on the motor shaft V. Each piston rod (*see* D), guided by the frame Q, carries a frame E, in which slides the crank pin M, itself fixed in a pinion G, which is thus compelled to turn. The three pinions G gear with the cog-wheel R, forming the fly-wheel keyed on the motor shaft.

The Simpson and Bodman three-cylinder single-action, direct, reversible motor has but one crank, and the cylinders are inclined at 120° to one another (Figs. 64 and 65, pp. 88 and 89). The metals used in constructing it are aluminium, cast-iron, and phosphor-bronze, the wrought work being of mild steel; the cylinders and pistons are of steel. Admission is effected by simple mushroom valves with spring-loaded stems reciprocated by means of a cam turned on a sleeve mounted on the main shaft; upon this sleeve is another cam. By moving this sleeve in an axial direction direct and reverse rotation are obtained, and for an intermediate position the motor stops, the valves then being seated. The exhaust is led to a feed tank or passes

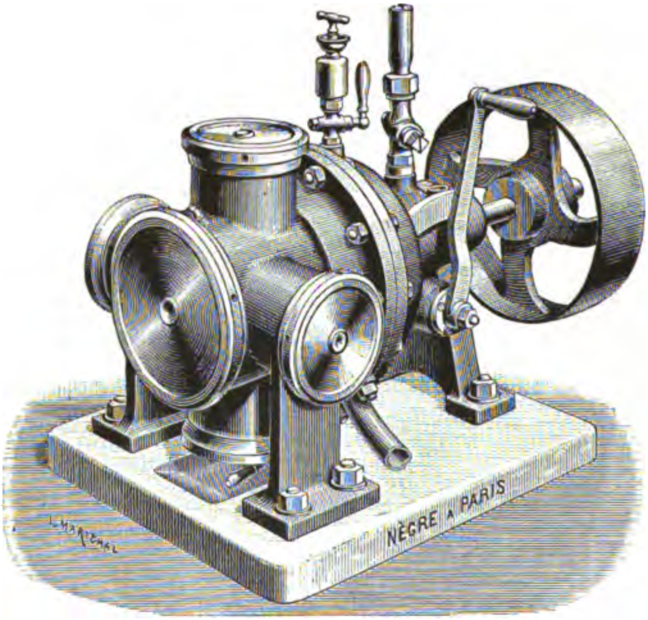
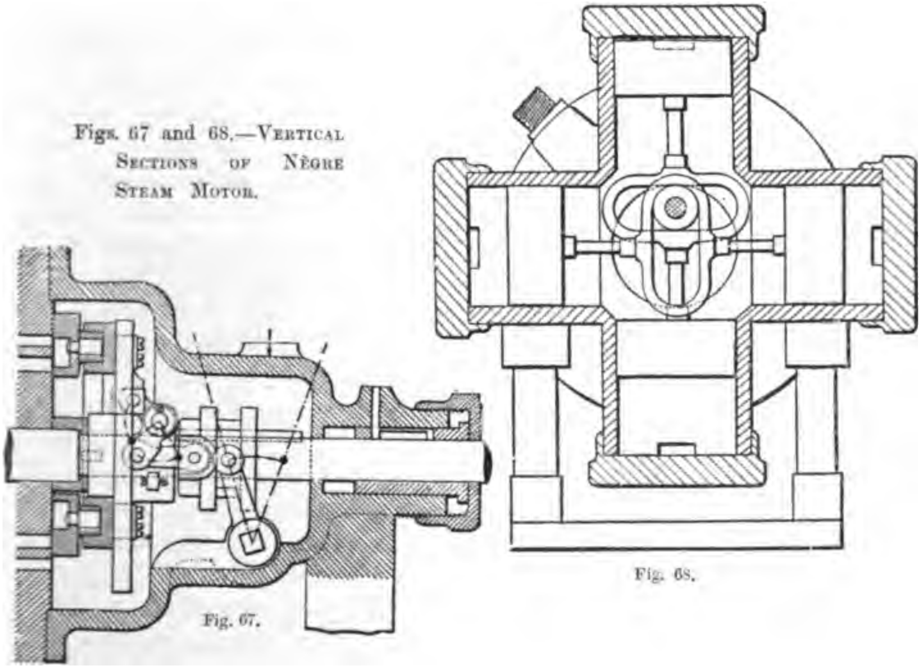


Fig. 66.—Nègre Steam Motor.

off as invisible gas up the funnel. As there are no glands in the motor, superheated steam can be used with advantage. The admission valves also are safety valves, as, should water enter, the valves simply lift. The following are the letter references in Figs. 64 and 65: A is the casing; B, bearing and water jacket; C, reversing cover; D, cylinder; E, piston; F, connecting rod; G, crank and shaft; H, cam; I, reversing spindle; J, reversing action; K, cam rod; L, valve and stem; M, steam connections; N, governor; O, exhaust; P, driving pinion; Q, attachment to vehicle; and R, spur wheel bearing. The complete motor, with gear case, etc., as fitted on a 3-ton to 5-ton lurry, weighs but 100 kg. (2 cwt.), and the power is 8½ brake horse-power at a steam pressure of 7 kg. per cm^2. (100 lb. per sq. in.), and a speed of 500 revolutions per minute. Its running is exceptionally steady. The Simpson and Bodman lurry has two such motors, one on each side, each actuating its own driving wheel, and they have nothing in common except the steam and exhaust pipes.



Figs. 67 and 68.—Vertical Sections of Nègre Steam Motor.

Fig. 67.

Fig. 68.

In the Nègre motor, as shown by Figs. 66 to 68, the four cylinders are arranged in form of a cross The four single-action pistons have their opposite rods extended and connected by an elliptic frame (*see* Fig. 68). The two frames fit a roller, the axle of which is an eccentric pin fixed to the motor shaft. Distribution is by two flat slide valves worked by a single eccentric. When admission begins behind one piston, and exhaust begins behind the opposite one, the two other pistons are at the middle of their stroke. Consequently there are not any dead points, and the action of the motor on the shaft is more regular. Steam is admitted into the valve chest by the upper tube (Fig. 66); and having done its work, it escapes into a channel communicating with the pipe to be seen low down to the right in Fig. 66. When the reversing gear lever is moved from one extreme position to the other, the valves slide on their plate and reverse the distribution. The intermediary positions correspond to variations of expansion, and the middle position to stoppage. A Nègre motor with pistons of 10 cm. (4 in.) diameter and 6 cm. (2·4 in.) stroke, fed by steam at 10 kg. per cm.^{2} (142 lb. per sq. in.), gives 8 h.p. at 200 revolutions per minute; with steam at 15 kg. per cm.^{2} (213 lb. per sq. in.), it gives 12 h.p. at 400 revolutions per minute; and from 15 h.p. to 20 h.p. at 1,000 revolutions per minute.

The Reading steam motor is another American construction. The 5¾ h.p. motor has four single-acting vertical cylinders cast in one piece, the bore being 6·35 cm. (2·5 in.) and the piston stroke 8·9 cm. (3·5 in.). Two pistons work on the ends of one crank-shaft and two others on a separate crank-shaft; these two shafts revolve in the same direction, and each carries a spur wheel meshing with a common spur wheel on a cross shaft, which chain drives the live rear axle. All four cranks are at 90° from one another. The rotary valve gearing is placed on the cylinder covers, and the horizontal valve disc is rotated by a spur wheel carried on the end of a vertical shaft, which is driven through two mitre wheels by the main shaft of the motor; the valve revolves at one-third the speed of the crank-shaft, and the ports provide for a fixed cut-off at five-eighths of the stroke. The reversing gear is an ingenious arrangement of links between a sliding sleeve on the valve shaft and the spur wheel that drives it. The 5¾ h.p. is developed at a steam pressure of 17·5 kg. per cm.^{2} (250 lb. per sq. in.), and at a speed of 960 revolutions per minute.

A larger type of Reading motor shows a few improvements on the above. Roller bearings replace the plain bearings. The horizontal valve is replaced by a vertical one, driven in the same manner as before, consisting of a large iron cylinder provided with the necessary ports, and fitting into a brass sleeve, which is forced down into place between the four cylinders. The steam inlet and the exhaust pipe are connected with it through the main casing. A new reversing gear is obtained by cutting in two the vertical shaft that drives the valve, and then fitting a bevel gear to the two ends thus formed; a third bevel wheel is placed in mesh with this new gear, and is rocked about the axis of the vertical shaft. This avoids much back lash, and gives simpler construction.

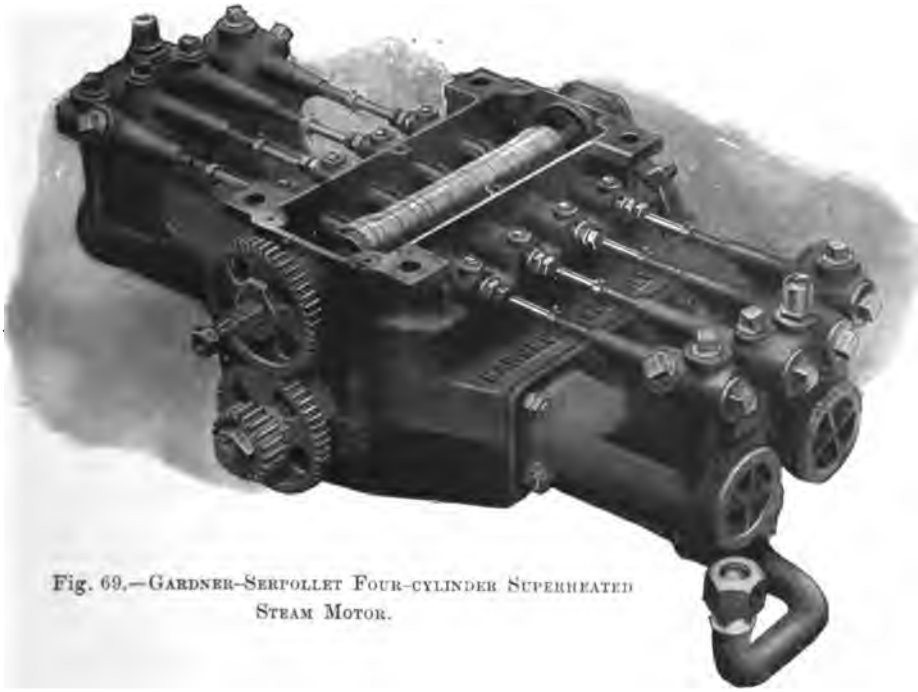


Fig. 69.—Gardner-Serpollet Four-cylinder Superheated Steam Motor.

The Gardner-Serpollet superheated steam motor, Fig. 69, has four single-acting cylinders arranged in two pairs facing each other. It is of utterly different construction from ordinary steam motors; in fact, its design resembles more that of a petrol motor. The facing cylinders work upon common crank pins, the two crank pins being at right angles to each other, so avoiding all dead centres and allowing the motor to start in either direction whatever may be the

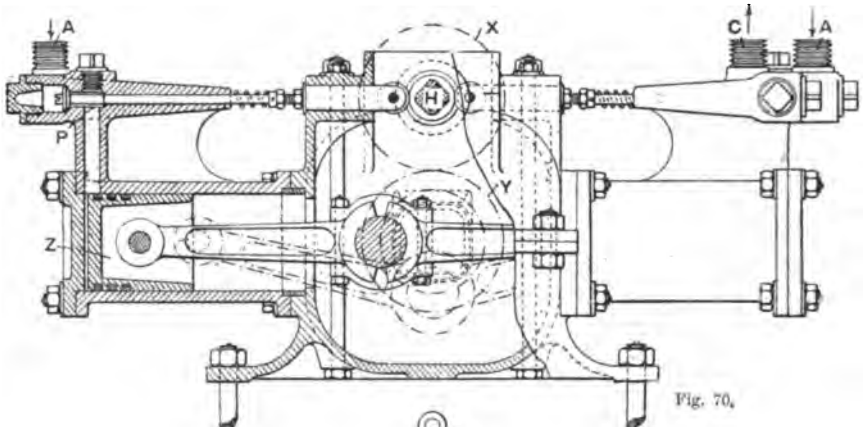


Fig. 70.

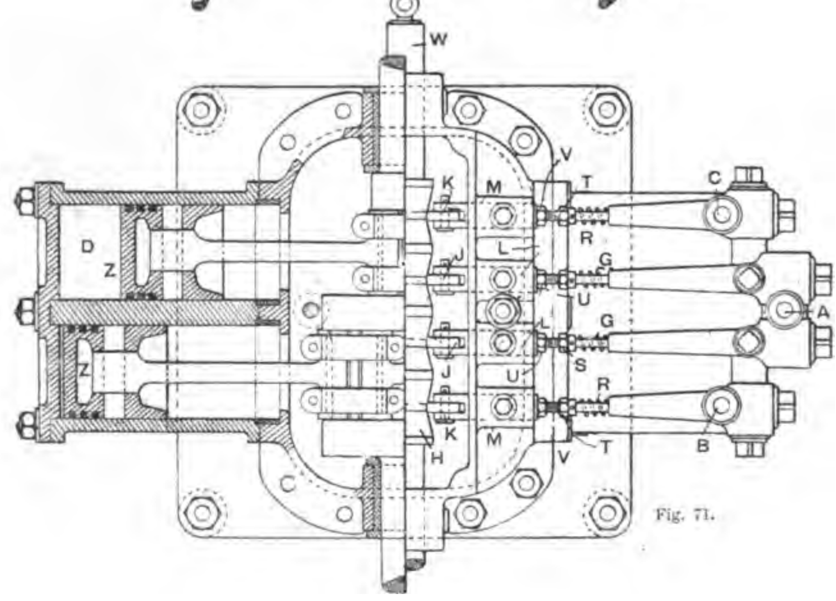


Fig. 71.

Figs. 70 and 71.—Elevation, Plan, and Sections of Serpollet Motor.

position of the crank-shaft. The high temperature of the superheated steam precludes the use of stuffing boxes, and the ordinary slide or piston valves have been replaced by mushroom or poppet valves resembling those used on petrol motors. A feature of the motor is a special central composite cam, spur-driven from the crank shaft, which opens both the steam inlet and exhaust valves against the action of springs; the cam can be slid in the direction of its own length along its shaft so as to (1) vary the cut-off, that is, the moment of closing the inlet valves during the forward stroke of the piston; (2) cease to open inlet and exhaust valves; (3) open the valves at such periods when the position of the crank-shaft shall cause rotation in the opposite direction. The valve gear is described in detail below.

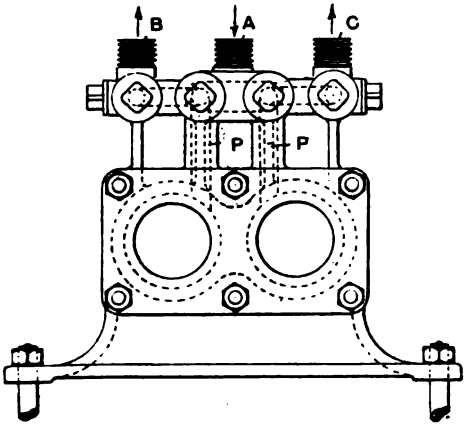


Fig. 72.—End Elevation of Serpollet Motor.

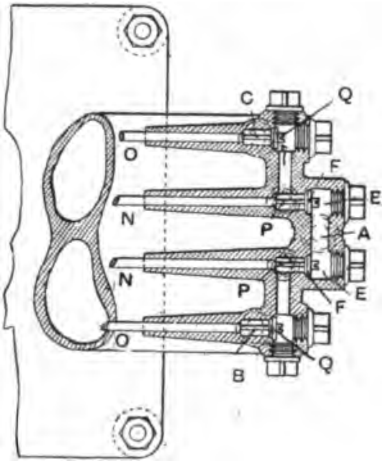


Fig. 73.—Sectional Plan of Serpollet Valves.

Fig. 70 is partly a side elevation of the Gardner-Serpollet motor and partly a vertical section taken through the axis of a cylinder and admission valve; Fig. 71 is a plan and part horizontal section; Fig. 72 is an end elevation; and Fig. 73 is a sectional plan of the admission and exhaust valves of two of the cylinders, the path of the steam from the inlet pipe to the exhaust pipe being indicated by arrows. The high-pressure superheated steam from the boiler (see p. 64) enters at A and exhausts at B or C after use in the cylinders D; the pistons are shown at Z. From the inlet A the steam passes into the valve-box E, in which are the admission valves F, held on their seats by the steam pressure and by springs, G; they are opened more or less by means of the central multiple cam H, acting through rollers J and slide rods L on the valve rods N. As soon as one of the admission valves F is open the steam passes to the corresponding cylinder through one of the passages, P, and returns by the same passage after expansion has taken place and the piston has begun its return stroke. The exhaust portions of the cam H act consecutively through rollers, K, and sliding rods, M, upon the rods O of the exhaust valves Q, which open until the piston has reached a certain point in the return stroke, when the cam H having rotated sufficiently allows the exhaust valves Q to close under the action of the steam pressure and springs R, and the steam remaining in the cylinder is thus compressed. Between each valve rod N O and the cam H are the sliding rods L M; one end of these is forked and carries a roller, J K, whilst the other end carries a set screw, S T, whose effective length can be varied and fixed by means of a lock-nut, U V, so as to take up all wear likely to arise and ensure perfect contact at all times between the cam and rollers, and between the sliding rods and valve rods. In this description the letters G, J, L, N, P, S and U refer to the inlet valve gear, and the letters K, M, O, Q, R, T and V refer to the exhaust valve gear.

The distribution cam H is above the oil bath, and its axis is in the same vertical plane as that of the motor shaft; this cam has on each side as many intermediate cylindrical stopping surfaces as there are rollers on that side; the rollers J K bear on the surfaces when the motor is stopped, and are then each in a depression between two opposite inclines, which terminate in cylindrical surfaces corresponding to the maximum admission and exhaust. The cam H is in one piece with a square shaft, W, which may be slid in either direction of its length by means of a forked lever operated by hand, or by the motor governor, so as to alter simultaneously and equally the positions of the admission and exhaust valves. On the end of shaft W is a toothed wheel, X, engaging with a wheel of the same diameter, Y, keyed to the shaft. (This is much better shown in the reproduced photograph, Fig. 69.) The relative positions of these two wheels may be altered by moving X forwards or backwards—for example, by one tooth—in relation to wheel Y, so as to cause an earlier or later admission and exhaust. The shaft W is driven by the crank-shaft through the toothed wheels X Y, and can slide freely through X and through a bush mounted in the frame at the other side.

Steam motors with six cylinders may have brief mention. Certain Serpollet motors had six cylinders instead of two or four. In a

Clarkson-Capel 8 h.p. motor there were six single-acting cylinders, 50 mm. (1·97 in.) in diameter, and 150 mm. (5·9 in.) stroke. The multiplicity of cylinders gave such great regularity of working that the engine could dispense with a fly-wheel, and the cranks were so accurately balanced that the motor could run full speed "merely suspended from a cord." Distribution and reversion were accomplished by slides and eccentrics. The engine was fed by water, largely, from the tubular condenser, 315 mm. (12·4 in.) long, to which spiral wire rings were attached, to act as radiators; besides these, the condenser was cooled constantly by a fan. The six-cylinder engine is reported to have run in the workshop for 24 consecutive hours, losing less than 22 l. (39 pt.) of water. It is not known whether this motor was ever used on a road vehicle; it is not of the type in use on modern Clarkson-Capel cars, light or heavy.

Alternating double-expansion motors with two cylinders are represented by the de Dion-Bouton, Gillett, Liquid Fuel Engineering Company's, and by some more modern motors, include the Thornycroft. In the de Dion-Bouton motor the two cylinders are horizontal, one on each side of the longitudinal axle of the car, and the cranks are geared at 90° to assure regularity of working and to facilitate starting. A special "recovering" valve allows steam to be admitted into the large cylinder when an extra effort is needed. In some of these motors expansion is uniform by 25 per cent., and in these, by acting on the steam valve, admission and work are made to vary. Most of those now constructed have a normal rate for admission of 75 per cent., but this can be varied by the Walschaërt slide. All the moving parts of the motor are enclosed in a cast-iron gear-case, which acts as a frame, lubrication then being simply effected by shaking. For purposes of inspection, two large sides and a lid can be removed from the case.

In the Motor Omnibus Syndicate's Gillett motor, of the steam-hammer type, with reversing gear, the cylinders are respectively of 100 mm. (3·9 in.) and 200 mm. (7·8 in.) diameter; their common stroke is 125 mm. (4·9 in.), and the motor makes 600 revolutions per minute at a speed of 12 miles per hour. It drives an omnibus with 25 seats, and, for starting, the steam can be admitted directly into the large cylinder.

The Liquid Fuel Engineering Co.'s (Lifu) motor had two horizontal cylinders. The cranks, slides, connecting rods, eccentrics, and pump-gear work in boxes half filled with oil, into which water cannot enter from the cylinder. The method of distribution, by

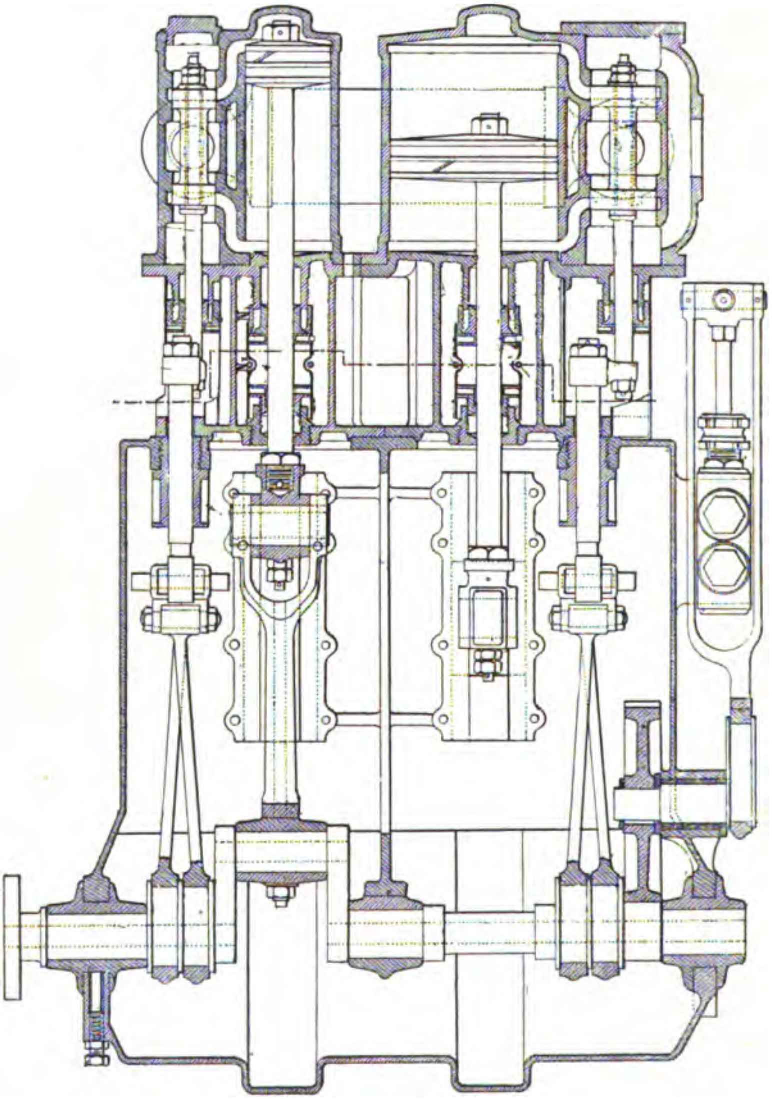


Fig. 74.—Lifu Horizontal Compound Steam Motor.

means of cylindric slide valves, is clearly illustrated by Fig. 74.

The Thornycroft patent steam motor, shown in section by Fig. 75, is horizontal, compound, and reversing. Its cylinders are 10·16 cm. (4 in.) and 17·8 cm. (7 in.) in diameter by 12·7 cm. (5 in.) stroke, with constant lead; the special radial valve gear permits of any degree of linking up. A motor having these dimensions propelled a 2½-ton waggon and a 5-ton lurry at the Liverpool heavy vehicle trials of 1898. The two cut-off notches are at five-eighths and seven-eighths of the stroke. The lubrication is by the splash method, the whole mechanism being enclosed in an oil-tight, dust-proof casing, in which, however, all parts are readily accessible. The exhaust passes through the feed-water heater, and thence to the smoke-box, in which is a spark arrester; the draught created by the exhaust draws all the flue gases through the arrester. The engine is said to have a power of 30 h.p. at 500 revolutions per minute.

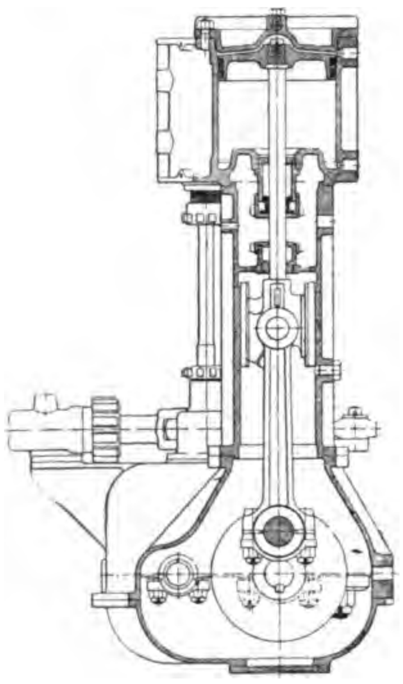


Fig. 75.—Thornycroft Horizontal Compound Steam Motor.

Of alternating double-expansion motors with three cylinders, the Bourdon-Weidknecht motor is a type. This is a three-cylinder compound motor for service in an omnibus having 30 seats. The motor has two extreme admitting cylinders, with cranks keyed at 90°, and a reducing valve with a crank at 135° to the preceding. The distributor, with reversing gear and variable expansion, gives an admission of from 10 to 87 per cent. This motor develops nominally 25 h.p., and, exceptionally, 30 and even 35 h.p. About 1 h.p. must be reckoned for every passenger to be sure of starting and running along the rising gradients of from 5 to 7 per cent. at a speed of from 8 km. to 12 km. (5 to 7·5 miles) per hour. For 25 h.p. the consumption is about 3 kg. of coke and from 18 l. to 22 l. of water per km. (10·6 lb. coke and from 52 pt. to 63 pt. water per mile). For an omnibus with 16 seats Bourdon and Weidknecht abandoned the compound system, employing instead a motor with equal cylinders.

The Coulthard steam motor and transmission gear, forming one mechanism, is illustrated in side elevation by Fig. 76, and in part plan and in part horizontal section by Fig. 77. The transmission gear is described on p. 365. The motor is of the compound, link-reversing

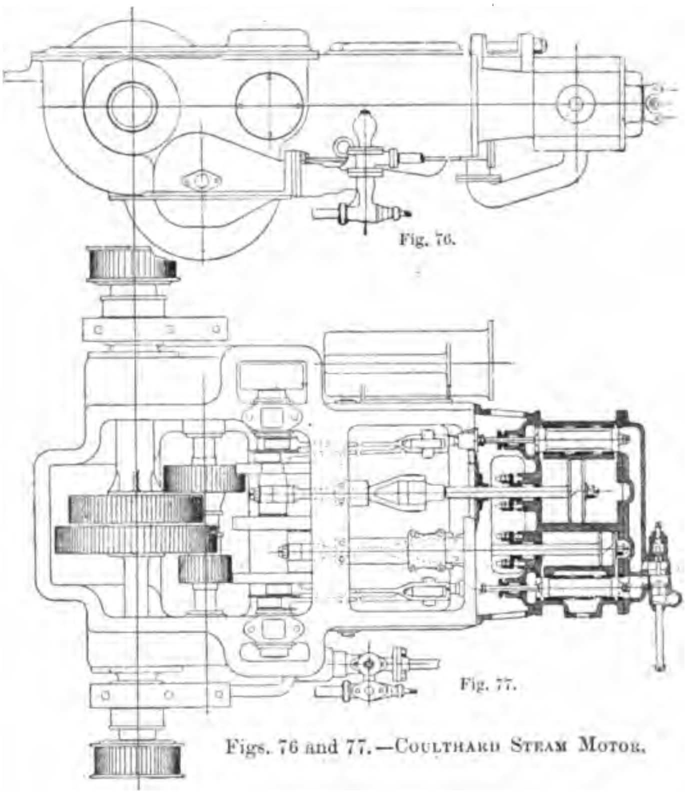


Fig. 76.

Fig. 77.

Figs. 76 and 77.—Coulthard Steam Motor.

gear pattern, claimed to develop 25 brake horse-power at the normal speed of 450 revolutions per minute. The cylinders are 9·5 cm. and 17·7 cm. (3¾ in. and 7 in.) in diameter, and the stroke is 15·2 cm. (6 in.). Only one cover is used for both cylinders and piston valves, this cover serving also as the receiver, whilst supporting the multiplier which is used for admitting live steam to the low-pressure cylinder; the exhaust from the high-pressure cylinder is diverted to the atmosphere. The Coulthard multiplier also serves as a relief valve, thus preventing damage through water accumulating in the cylinders. Stuffing-boxes are not used. The steam regulator is a balanced valve attached to the high-pressure cylinder steam chest.

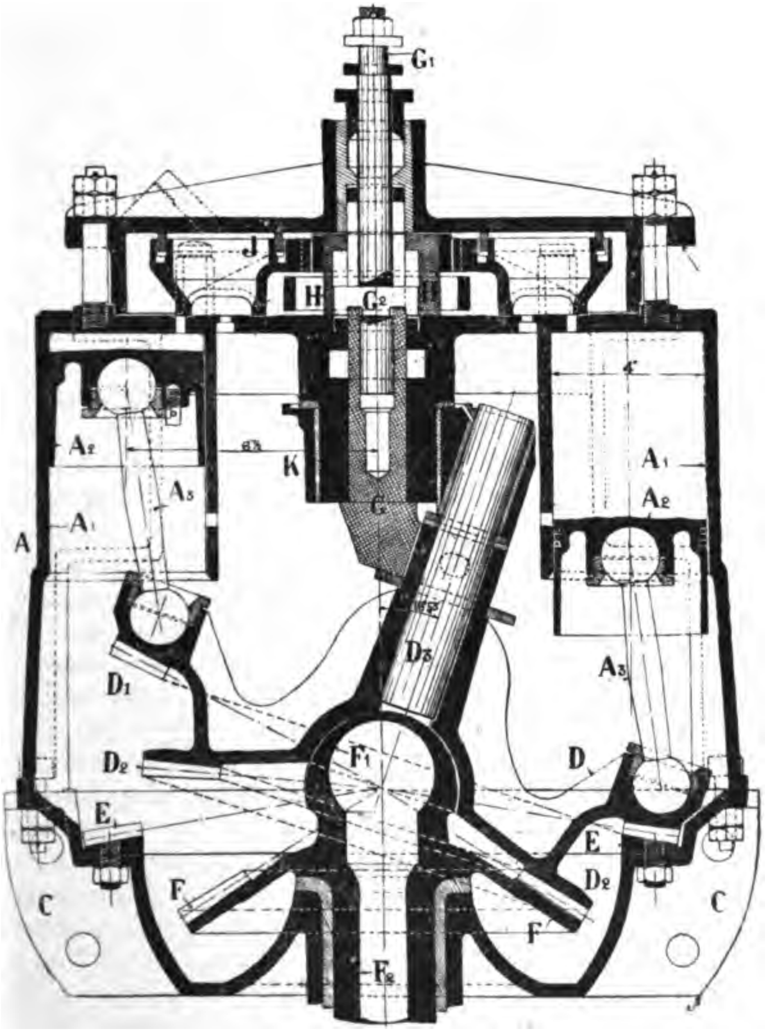


Fig. 78.—Section of Pioneer Steam Motor.

The Pioneer steam lurry employs two motors, one high pressure and the other fed with the exhaust low-pressure steam from the former. Both have practically the same construction, which is worthy of attention, and each is connected through a vertical shaft and bevel gearing to one of the front road wheels. These wheels thus are driven each by an independent motor, the rear wheels being the steering wheels and arranged on the Ackermann system. The section (Fig. 78) of the low-pressure engine shows the construction of both the motors. A casting (A) forms four vertical single-acting cylinders (A^1), parallel to and equidistant from each other. The four pistons A^2 have connecting rods A^3, with ball and socket joints at each end, as shown clearly. The lower ends of the pistons are connected with a "wobble" gear D, which comprises two bevel gear wheels D^1 and D^2 in one piece, which is turned out centrally on its under face to receive the upwardly projecting shaft D^3, and to form a ball socket. It is supported by ball F^1 fitting in the socket, and by shaft D^3 carried in bracket K. This bracket revolves freely about a central downwardly projecting sleeve, a part of the main casting A; and through the centre of the sleeve is the valve-operating shaft G. The reciprocating motions of the cylinder pistons give a gyratory motion to the gear piece D, and the gear wheel D^1 meshes with a horizontal gear ring E, having teeth on its upper side fixed to the lower casing C of the motor. The periphery of wheel D^1 rolls round the fixed ring E in such a manner that a few of its teeth are always in mesh with a few corresponding teeth in the fixed toothed ring. As D^1 and E have the same number of teeth, the "wobble" piece D, operated by the connecting rods, is prevented from rotating about the vertical centre line of the motor. The energy is transmitted from the gyrating parts to the vertical main driving shaft F^2, which is carried downwards with its axis central with the motor. A special speed-reducing gear is placed between the gyrating shaft and the vertical driving shaft; the upper end of the last-named forms the ball F^1, upon which the gear piece D is universally socketed. Power from the gyrating wheel D^2 is transmitted to the driving shaft by bevel wheel F solid with the shaft. In this "seeking-tooth" type of gear the resulting speed of the vertical driving shaft is the difference between the number of teeth in two gear wheels; wheel D^2 having 42 teeth and wheel F only 39; the speed reduction is in the ratio of 14 to 1.

The engine valves J are of the slide-valve type, work on horizontal-faces above the cylinders, and are operated by an eccentric, H, carried on the vertical shaft G, which passes down between the four cylinders, and is driven by the gyrating shaft D^3, through the crank shown in Fig. 78. The cut-off can be varied from zero to three-fourths, and the valves are given a forward or backward lead by raising or lowering an internal shaft G^1 which projects through the top of the motor casing, and slides inside the shaft G. This internal shaft is connected to the eccentric block by a cross-pin G^2, which moves in a diagonal slot in the eccentric, to which is so given a variable eccentricity. The eccentricity gradually is reduced to nil, and then increased to maximum on the opposite side of the shaft G by raising or lowering the sliding shaft G^1. There are two motors, remember, and their sliding shafts G^1 are interconnected so as nominally to be operated simultaneously by the driver, who can vary the cut-off from maximum forward to maximum backward by means of a horizontal pedal, fulcrumed at its centre, one foot being placed on each end; the pedal lies across the car. The four steam-jacketed cylinders of the high-pressure motor are 7·6 cm. (3 in.) bore and 11·4 cm. (4·5 in.) piston stroke. In the low-pressure motor the four cylinders are of 12 cm. (4·75 in.) bore and 11·4 cm. (4·5 in.) piston stroke, and are not jacketed. The vertical slow-speed driving shafts of the two motors are connected by "lathe carrier" type flexible couplings to other vertical shafts immediately beneath and in line with them; the latter are carried in long bearings in the fixed axle, and are fitted with bevel wheels which mesh with larger bevel wheel rings secured to the front road wheels. The flexible coupling allows the axle to rise or fall to the extent permitted by the semi-elliptic springs which support it, and each wheel is thus driven independently by a separate motor, and differential gear is dispensed with.

As regards rotary motors, it may be remarked how rational would be their application to automobiles, and the endeavours made by some constructors to realise this idea cannot but meet with approval. Experiments have resulted in the invention of interesting types of rotary motors for road use, but these, unfortunately, have not yet given satisfaction in practice. Gauthier and Wehrlé studied a rotary engine in which distribution is accomplished by aid of a palette which the steam (or gaseous mixture) presses against the cylinder, acting as a piston. To run with gas, two of these motors are coupled, the first sucking in the mixture and forcing it after compression into the second.

The Compagnie Générale des Automobiles, of which M. Triouleyre is director, built a steam omnibus, which is driven by a rotary epicycloidal motor (A. G. system), represented by Figs. 79 to 82. Three discs D are keyed eccentrically in B, on the motor shaft, and, under pressure of steam, rotate a cylindrical drum: in this movement any point of one of the discs describes an epicycloid, whence the term epicycloidal applied to the motor. Fig. 79 corresponds to the period of admission for the compartment under consideration; the inclination of the hemispherical cap H, which is followed along half its circumference, allows the steam coming from orifice E, through the slide valve G, to enter the cylinder, where it forces the disc D to roll on the cylinder. When the disc reaches the lower part of the cylinder the solid part of the cap H shuts off the steam; then admission ceases, and expansion begins (*see* Fig. 80). When the piston disc is in the position of Fig. 81, the orifice F begins to uncover, and this is the beginning of the exhaust period. With a motor of this kind all speeds intermediary between 60 and 24,000 revolutions per minute were obtained. The possibility of running at a slow rate allows great simplification, if not the entire suppression, of the trains of reducing gear generally needed with rotary motors. Consumption of steam at the first trials was less than 25 kg. (55 lb.) per horse-power hour. In further explanation of the motor, particular attention is directed to the two vertical sections (Figs. 81 and 82). In these figures A A are partitions dividing the

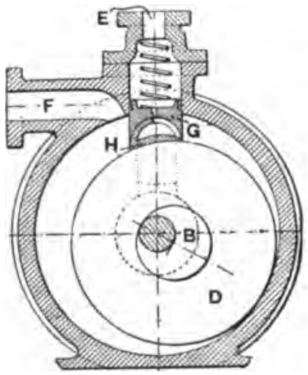


Fig. 79.—Gerard Rotary Steam Motor: Admission Period.

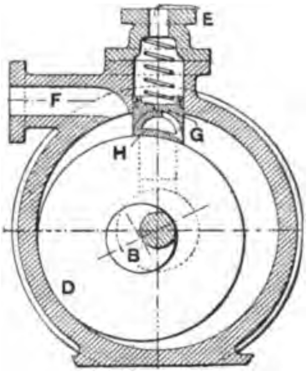
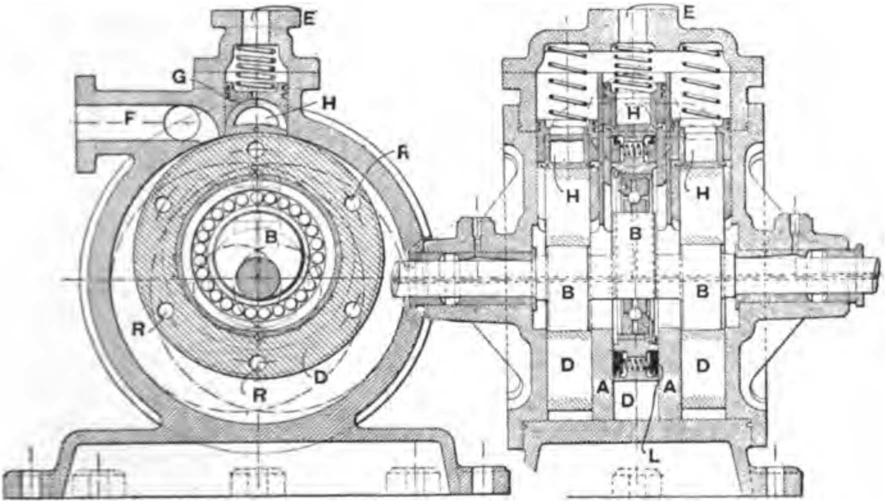


Fig. 80.—Gerard Motor: Expansion Period.

cylindrical body into three compartments, each reserved for a piston disc D; the projections B on the motor shaft keyed at 120° from each other, and acting as cranks for the piston discs, with ball bearings to lessen friction; eccentric piston discs D on the motor shaft are caused to roll in the cylindrical drums, where they are housed; E F are admission and exhaust orifices for steam; distributing valves are shown at G; jointed caps are shown at H, and these regulate expansion by the inclinations they acquire by following the movements of discs D; L L are segment stops to close



Figs. 81 and 82.—Vertical Sections of Gerard Rotary Steam Motor.

the space between the sides of the discs and the partitions or the cylinder ends; along the part where the discs roll against the cylinder a close fit is obtained by the steam pressure on the discs; R R are springs pressing the segment stops L L against the partitions and ends of cylinder.

The Arbel-Tihon rotary motor, exhibited at the Tuileries, Paris, in 1898, is illustrated in sectional elevation by Fig. 83; the following description of it is by R. Soreau. The body of the pump is a horizontal cylinder surmounted by a cap in which is the valve gear. The piston is formed first of another cylinder of same length guided so as to roll on the pump barrel; in this way the cylinder surrounds two cams fixed on the motor shaft; second, a partition, which forms one with the movable cylinder, and slides in a knee placed at the base of the cap. Two cocks are placed symmetrically with regard to the knee, one for admission and the other for exhaustion, both being worked by the same handle, so that when one is opened the other is shut and the direction is reversed. Under pressure of steam the advance of the piston cylinder through the agency of the connecting rods causes the two cams to advance and consequently the motor shaft to rotate. The joints are made tight with cork plugs driven with great pressure into pockets so as to be flush with the sides of the piston. These plugs swell from moisture of the steam, and are said to form good joints with very slight friction. A single lubricator suffices for all the surfaces. A 140-kg. (308 lb.) motor gives 6 h.p. on the shaft with steam at 10 kg. per cm.^{2} (142 lb. per sq. in.)

De Lambilly exhibited at the Tuileries, Paris, in 1899 a rotary motor characterised by simultaneous working of two palettes, which drive the motor shaft by aid of a ring keyed on it, one of the palettes being worked outside the ring, whilst the other is inside. Distribution and reversing are accomplished by oscillation in one direction or the other of a disc furnished with a handle and perforated with two holes which come into communication with the ports in the end of the motor for admission and exhaust. Tight joints are assured by regulating the cylinder (inside which the piston ring turns) in a vertical direction, and the piston ring horizontally, and by the action of springs pressing the movable segments of the palettes against the sides of the cylinder. The work done by the type exhibited is theoretically 9 kgm. per revolution at per kg. of pressure per cm.^{2}, this being equivalent to 65 ft.-lb. at a pressure of 14 lb. per sq. in.; the motor easily could make 1,500 revolutions per minute and give 8 h.p.

A few general considerations with regard to steam motors may now be stated. Simplicity is all-important. The compound system should be reserved for heavy cars, because multiple expansion has not any appreciable effect except for powerful engines. It is estimated that only with a motor having a minimum of 15 h.p. does the economy caused by the better utilisation of water compensate for the increase in weight and the expense of a second cylinder. Lencauchez rightly recommends superheating the cylinder jackets by a current of high-pressure steam. He also demonstrated that condensation of steam is not essential to obtain a minimum consumption, and therefore it is not to be greatly regretted that the water condenser, owing to the amount of water it consumes, cannot be employed for automobiles. On the other hand, the air condenser should be adopted, because the water can be utilised a second time, and it increases the distance that can be run without new supplies. This point has a greater importance when it is remembered that it is necessary to obtain water of a suitable quality to avoid scale. A condenser must be lubricated with mineral oil, as any other is saponified, especially at high pressures, and the organic acids liberated corrode the tubes. Even mineral oil must not be allowed to enter the boiler in any considerable quantity, because if it spread over the sides there would be a risk of fire. Improvements are to be desired, for though the steam motor already has had a long career, its efficiency, as shown on p. 806, is very limited. A de Dion-Bouton motor of from 25 to 35 h.p., to give the automobile a speed of 18 km. (11·2 miles) per hour, consumes per horse-power hour 1·5 kg. (3·3 lb.) of coke, and 9 kg. (20 lb.) of steam, the latter being at a pressure of 7 kg. per cm.² (100 lb. per sq. in.).

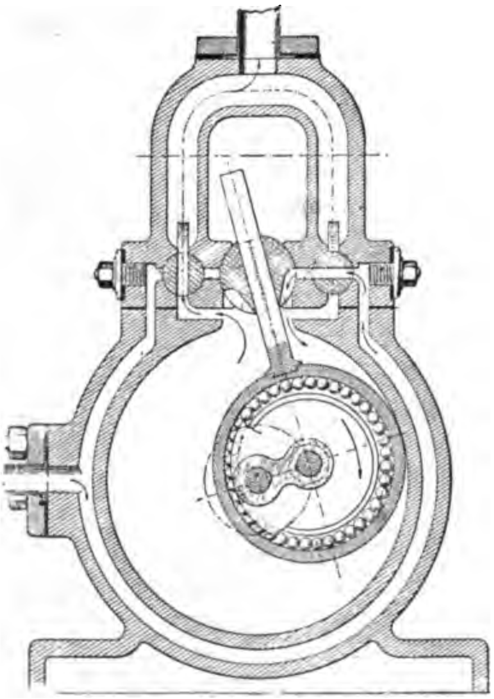


Fig. 83.—Arbel-Tihon Rotary Steam Motor.

The only great progress which can be expected is the construction of a practicable rotary motor. The steam turbine is not applicable to automobile service because its efficiency is only good at an exceedingly high speed, and this would necessitate the employment of very heavy reducing gear, which would absorb much of the work and lower the general efficiency.

CHAPTER V.

CARBURETTERS FOR PETROL MOTORS.

A CARBURETTER is employed in the preparation of the charge which is ignited in the cylinders of certain types of motors. Nearly all of these motors are driven by petrol spirit, which is a distillation of crude petroleum obtained between 70° and 120° C., and whose density, that is, specific gravity, varies from 0·690 to 0·735. Synonymous with petrol spirit are "petrol," "light oil," "mineral spirit," "moto-car spirit," "moto-essence," and "moto-naphtha," and American synonyms are gasoline and benzoline. The best French petrol spirit has a density of 0·700 at 15° C., and boils at 90° C. In any case the density or specific gravity should range from 0·675 to 0·710.

English petrol spirit has a density of 0·680 at 15·5° C. (60° F.). The following table gives the densities of English petrol spirit at various temperatures:—

DENSITY OF PETROL SPIRIT.

Temperature.		Density.	Temperature.		Density.	Temperature.		Density.
Centigrade.	Fahrenheit.		Centigrade.	Fahrenheit.		Centigrade.	Fahrenheit.	
Degrees.	Degrees.		Degrees.	Degrees.		Degrees.	Degrees.	
—1·1	30	·695	10	50	·685	21·1	70	·675
0	32	·694	11·1	52	·684	22·2	72	·674
1·1	34	·693	12·2	54	·683	23·3	74	·673
2·2	36	·692	13·3	56	·682	24·4	76	·672
3·3	38	·691	14·4	58	·681	25·5	78	·671
4·4	40	·690	15·5	60	·680	26·6	80	·670
5·5	42	·689	16·6	62	·679	27·7	82	·669
6·6	44	·688	17·7	64	·678	28·8	84	·668
7·7	46	·687	18·8	66	·677	30	86	·667
8·8	48	·686	20	68	·676	31·1	88	·666
						32·2	90	·665

If the petrol spirit tested with the densimeter is not at a temperature of 15° C. (59° F.), add or deduct from the indicated density as many times 0·8 as the thermometer records degrees above or below 15° C. Thus at 30° C. (86° F.) add 12 (0·8 × 15 = 12), and at minus

15° C. subtract 24 (0·8 × 30 = 24). The indications of the densimeter are not absolutely conclusive. Spirits made by mixing extra light benzolines and heavy petroleums can be brought to the required density and yet be worthless for automobile use, because in the carburetter the more volatile parts quickly separate from the others, and carburetting soon becomes impossible. A good spirit is made by rectifying and purifying with sulphuric acid and soda the distillate of crude petroleum within the prescribed limits of temperature given above. It is perfectly clear, with a mild odour, and a few drops poured on the palm of the hand rapidly evaporate without leaving any residue. Even when of good quality it is advisable not to utilise the dregs, that is the last few drops, left in the can. Good spirit of 0·700 density costs from 3½d. to 4d. per l. (1s. 3d. to 1s. 5·3d. per gal.) outside Paris. Half this price is customs duty. In Paris 1·99d. per l. (9d. per gal.) must be added for the octroi tax. From two points of view petrol spirit is greatly inferior to petroleum. It is more expensive, and its volatility is a permanent danger in handling. In America, where as a rule the bounds of prudence are not very carefully respected, the use of petrol spirit lamps is prohibited. It cannot, then, be insisted on too much that automobile drivers should handle petrol spirit cautiously and far away from any open flame. In spite of this, petrol spirit is preferred to the heavier petroleum, for the three following reasons. With it failure of ignition of the carburetted mixture is rarer, its combustion leaves very little residue, and fouls the motors much less. But the most important advantage is that preparation of the carburetted mixture is much simpler and safer with petrol spirit than with petroleum. The first essential of an automobile motor is simplicity. Now in the petroleum motor the carburetter is sometimes rather complicated. With petrol spirit, the explosive mixture can be made much more simply, as a detailed study of carburetters as used on automobiles will demonstrate.

To be explosive, the mixture of air and spirit vapour must be made in certain fixed proportions. If to one volume of vapour is added from 8 to 10 volumes of air, a rich gas, like illuminating gas, is obtained, which will burn without exploding. To have an explosive mixture, from 9 to 10 volumes more of air must be added to the mixture, which will then contain from 17 to 20 volumes of air and 1 of spirit vapour. In many carburetters the spirit vapour is diluted in two stages, and, in consequence, two distinct air inlets are necessary. The rich gas is prepared by evaporating the spirit in contact with the air, which is aided sometimes, especially in winter, by circulating around the liquid a part of the exhaust gas, or the water which has cooled the cylinder. Cold petrol spirit does not volatilise sufficiently, and hot spirit does so to excess; so that to preserve it at the requisite temperature it must be possible to vary the quantity of hot exhaust gas or warm water applied to the heater. In the de Dion-Bouton tricycle, for example, there is, at the end of the heating pipe, a kind of screw plug, which can be used to vary the working section of this pipe. Frequently this screw plug is lost, and Wolff invented a substitute for it, his regulator being merely a bronze key fixed firmly in the place formerly occupied by the plug.

Contact of the two fluids (petrol spirit vapour and air) is obtained either by making the air bubble through the liquid, or simply causing the air to lick the spirit; but chiefly by previously atomising the latter. Consequently, the three classes of carburetters are distinguished as bubbling, surface, and atomising carburetters.

Bubbling carburetters are not much employed now, and, in any case, those which have not a constant level must be rejected; for if the air does not always pass through an equal depth of liquid it is not enriched uniformly. To improve such defective carburetters, P. Rapin has devised a regulating float which can be adapted without any difficulty.

In spite of the constancy of level, the degree of enriching may vary with the velocity with which the air passes; it certainly varies with the composition of the petrol spirit, which tends to liberate its more volatile parts, and gradually becomes impoverished. This is so much so that to obtain a constant and sufficient carburetting, and to avoid taking up the solid particles, which very quickly foul the cylinder, it becomes necessary to employ the carburetter from time to time without using up all the petrol spirit which it may contain. The bubbling carburetter has also the defect of being somewhat cumbersome, though, on the other hand, it is very simple. Constancy of level is easy to obtain automatically, by aid of a regulating float, or by the birds' drinking-fountain device. However, it is not much employed by first-class makers, though still used by Delahaye.

Surface carburetters are a more numerous class than the preceding one, but possess the same defects and good qualities, although constancy of level is not so important; they are perhaps even more cumbersome than those in the first class. The Tenting and old Benz carburetters belong to this type, as also does the first Lepape carburetter. The latter consists of a hot-water-jacketed vessel, in which the level of the petrol spirit is maintained constant, as in a birds' drinking fountain. One of the most interesting devices of this kind is certainly the old de Dion-Bouton carburetter, shown in Fig. 267, on p. 277, which has given such good results on tricycles. Referring to Fig. 267, the vessel A, filled with petrol spirit to a variable level, receives the air to be carburetted through the chimney B, which can slide in a cylinder, and is furnished at the lower part with a brass plate C, so as always to bring the current of air sufficiently near the petrol spirit; the air current, after licking the liquid, ascends along the sides. The top part of the carburetter forms a seat containing the two plugs of twin taps. To the left the seat has an opening communicating with the carburetter, and another opening into the air. Plug R^1, movable around its axis, has an opening which can be brought opposite one or the other of these orifices or both together. Thus this tap can admit pure air or petrol spirit, separately or together, in variable proportions. The mixture, thus proportioned at will, enters the plug R on the right, near the bottom, which is open, and by this tap and the prolonging pipe which passes through the carburetter it is conveyed to the cylinder. Taps R and R^1 are worked by levers with little handles placed on the higher tube of the tricycle frame. D is a float whose attached wire indicates the height of the petrol spirit.

In the Aster carburetter there is a float on the surface of the liquid to lessen the formation of waves due to the jolting of the vehicle. The metal plate under which the air licks the liquid is connected with this float, and then remains at a constant distance from the liquid; this device assures greater regularity in carburetting. The mixture thus formed becomes more intimate in a dome.

The Pope Manufacturing Company's carburetter has a small receptacle inside a large one, which enables cool petrol spirit to be run into the carburetter as soon as an extra effort is needed. The pure air to be mixed with the carburetted air enters through a pipe arranged with a baffle to prevent noise.

The Lufbery carburetter (Fig. 84) is of the float-feed kind, but the carburetting chamber A has a central pipe down which air is drawn, and the chamber is fitted with baffles around which the air has to pass on its way to the engine. The pressure in both chamber A and float-chamber B is kept constant by means of an air pipe C, and a coiled pipe D conveys some of the exhaust gases through the petrol spirit in chamber A and warms it. The admission of petrol spirit into the float-chamber B is controlled by an automatic needle-valve. The carburetted air passes to the motor cylinder through the pipe E, on top.

In the Petréano carburetter, Fig. 85, the motor exhaust gases run through a central pipe A, whose temperature and that of the cylinder B which surrounds it are increased; the pipe has a jacket C, of a spongy permeable asbestos fibre, constantly kept moist with the liquid to be vaporised, which is conveyed into the cylinder through an orifice in the top part; air enters by another orifice to be seen on the right of Fig. 85. There are four funnels, D, E, F, and G, two of which are also lined with asbestos, forming a baffle and thoroughly mixing the air and petrol spirit vapour; finally the carburetted air enters chamber H, passing thence through valve J to the motor cylinder. The holes K in the base of the funnel cones allow the denser portions of the liquid to flow away, as their slow evaporation might interfere with the regularity of carburetting. These denser portions accumulate at the bottom of the cylinder B, whence they can be run out by a tap shown to the right. This carburetter gives a very homogeneous mixture, which

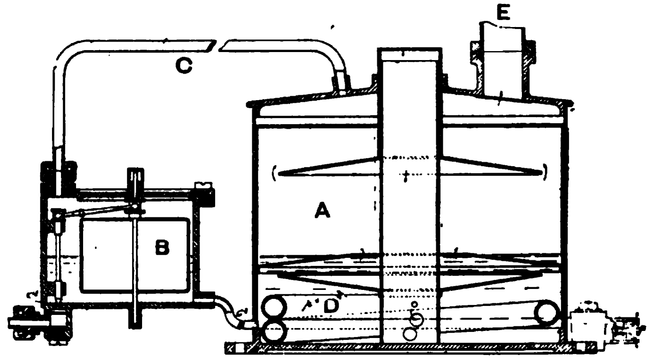


Fig. 84.—LUFBERY CARBURETTER.

burns in the most satisfactory way possible. Thorough mixture of the oil vapour and the air is really of the greatest importance, of which Lenoir already had an idea, and Petréano, instructed by the studies of Bandsept and Denayrouse, has since 1896 endeavoured to realise this perfect mixture. This thorough diffusion of the vapour makes combustion more sudden and more complete, and the Petréano system gives very good results with alcohol, it seems.

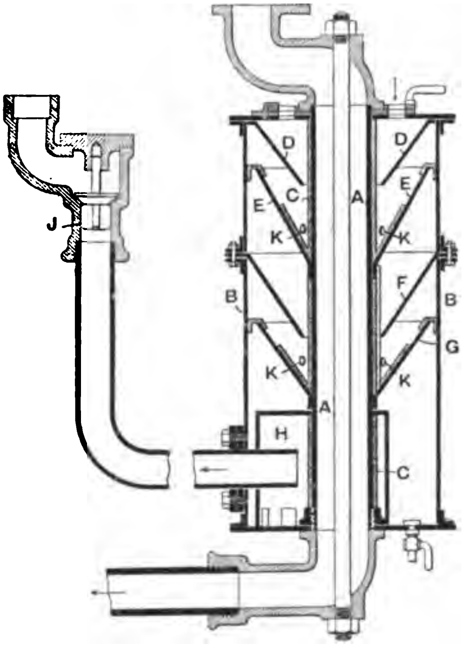


Fig. 85.—Petréano Carburetter.

A surface carburetter with zig-zag baffle plates constitutes Faure's latest device for use chiefly on motor cycles. Fig. 86 shows a section of it. The tank A is filled through pipe B, which also serves as the pure air inlet, H being a screw stopper with a regulating cock J. The partitions D E F G form zig-zag baffles, and have open-work trellises or gratings at K; these baffles prevent the spirit from being spirted into the motor supply pipe C, and assist to make the mixture of vapour and air more intimate. The inlet pipe B passes right through the baffle plate E, but the outlet C only just dips inside the tank. The arrow-line shows the course of the vaporised spirit.

The Roussy de Sales or Sales and Braby carburetter (Figs. 87 and 88) is a box 1, divided into compartments, 2 and 3, by the partition 4. The petrol spirit enters compartment 2 by pipe 5, whose orifice is opened by the needle 6, under the action of the lever 7, brought near by spring 8 and repelled by rod 9 of the piston 10. The piston ascends inside the cylinder 11 under the influence of the motor's suction, and unmasks the orifice 12, by which the air is admitted through openings 13 into box 14, furnished on its upper part with alternate layers of wire gauze and spongy textiles saturated with petrol spirit. The carburetted air passes to the motor cylinder through pipe 20, 21, after receiving through valve 23, worked by lever 24, the correct amount of fresh air; the name "charging-saturator" is given to this appliance.

Wicks are used in the Papillon carburetter and in the Balbi carburetter. The first, which was employed on the Tauzin voiturette, consists of two concentric boxes, forming a bell, in the centre of which a set of cotton wicks form a surface of evaporation. The air circulates between the two boxes and enters the lower one through orifices made all round on a level with the liquid; the liquid maintains an almost constant level. The Balbi carburetter, employed by Grivel for motor cycles, also consisted of two receptacles of circular section, one fitted into the other, and communicating with each other by a valve in the bottom of the lower vessel; a series of wicks was arranged on the circumference of the first.

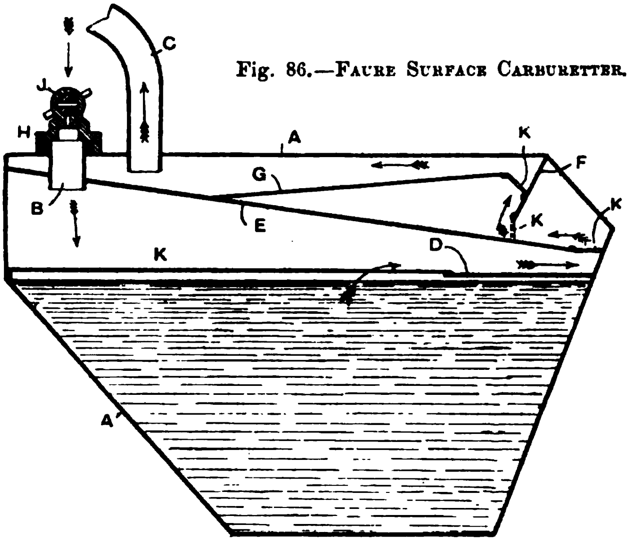
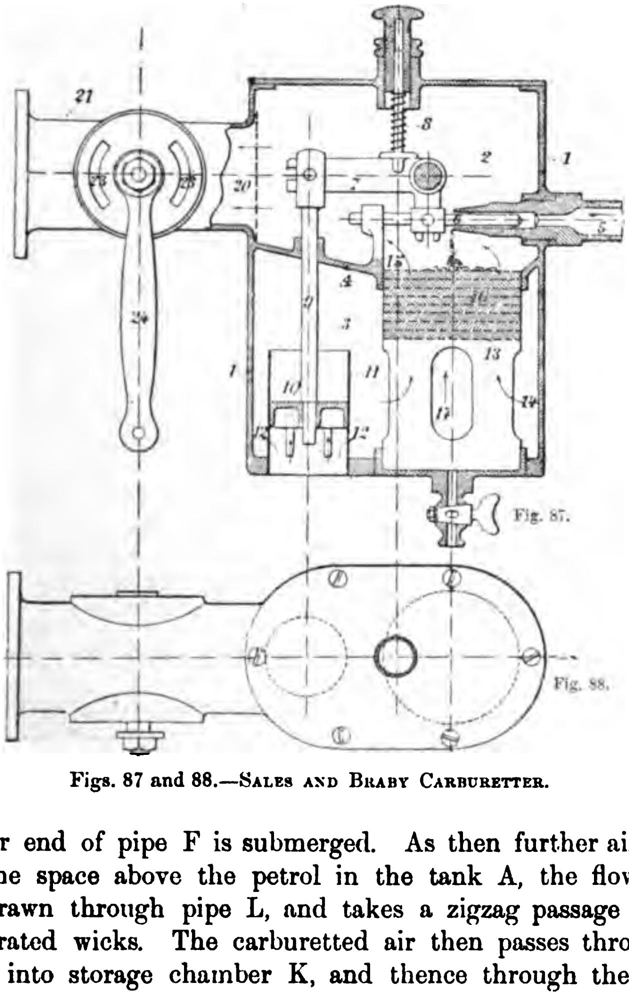


Fig. 86.—Faure Surface Carburetter.

The carburetter of W. G. Buck also is of the wick type, Fig. 89 showing a plan and Fig. 90 a sectional elevation. It has two chambers, the petrol tank A and the carburetting chamber C, connected by pipe D. From the top of the carburetting chamber depend twelve wicks, G, spaced as in Fig. 90. An air tube, F, leads from the bottom of the carburetting chamber, at the left, to the top of the petrol tank A. Operation is as follows:—When the air cock P in pipe H is opened, petrol passes through pipe D to the wick chamber until



Figs. 87 and 88.—Sales and Braby Carburetter.

the lower end of pipe F is submerged. As then further air cannot get to the space above the petrol in the tank A, the flow ceases. Air is drawn through pipe L, and takes a zigzag passage between the saturated wicks. The carburetted air then passes through the elbow J into storage chamber K, and thence through the filter Q and pipe L to the motor, automatically drawing in the auxiliary air through valve N. As the spirit in the carburetting chamber is absorbed, the mouth of the air pipe is uncovered, and fresh petrol flows in. There is a filter R in the air pipe H, and another (S) in the filling plug, both of these being constructed as at Q, to the left.

The Lanchester wick carburetter is as ingenious as is the rest of the Lanchester vehicle. There is something in the claim made that the wick carburetter gives a particularly constant mixture, owing to the fact that a wick does not discriminate between spirits of different density, and so it is not possible for the reservoir after a time to be half full of a spirit residue of too great density for use. The wick raises the spirit, and warm air from the motor surface volatilises it from the upper portions of the wick. Should water get into the petrol tank, it will not be raised by the wick owing to the antagonism between the oil and water. Fig. 91 shows a section of the carburetter, A being the petrol spirit tank within the main supply tank, B petrol, C wick tank, D wick, E pump handle, F mixture regulator with handle, G, H hot air inlet, and J overflow holes. The pump raises spirit from the main tank to the wick tank, a few strokes sufficing for about 16 km. (10 miles) or so, and the pump handle is conveniently near the driver's right hand. The mixture regulator is shown in the intermediate position, and the single-headed arrows indicate the passage of the pure air, and the double-headed ones that of the carburetted air,

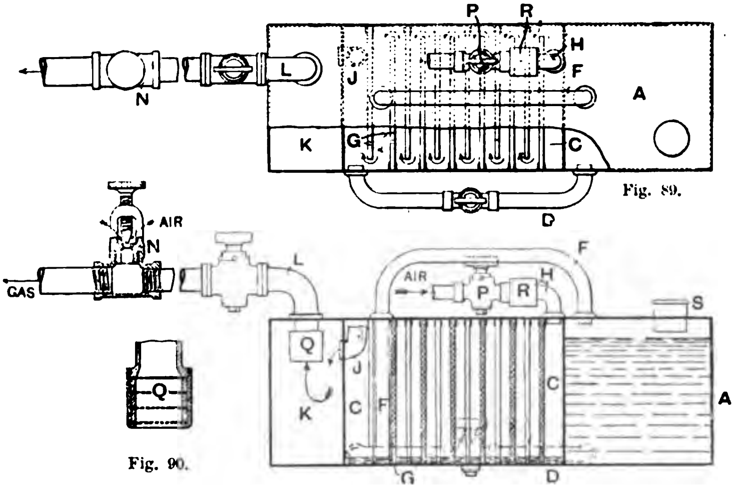


Fig. 89 and 90.—Plan and Sectional Elevation of Buck Wick Carburetter.

through the various ports. The additional air for combustion is supplied by the regulator F.

The Friedman carburetter is of American make, and is shown in section by Fig. 92. Instead of having a float-feed, perforated plates are made to act much in the same way as wicks in the wick carburetters. The petrol inlet needle valve is closed, whilst a leather tip A on the end of a vertical rod B is pressed upwards by a spring C. At the bottom of the rod is the disc D, just above the exit of the induction tube, and the piston suction acting on this disc pulls down the rod B and allows the spirit to fall from the valve upon the perforated plates where it is vaporised; the part containing the plates is exhaust-jacketed. At E the petrol enters, at F the mixture departs, and G is the jacket. This carburetter almost certainly uses up more power than one on the usual float-feed principle.

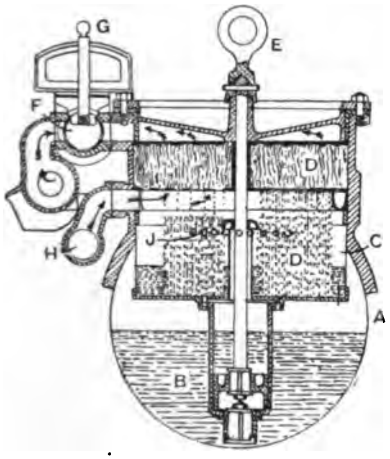


Fig. 91.—Lanchester Wick Carburetter.

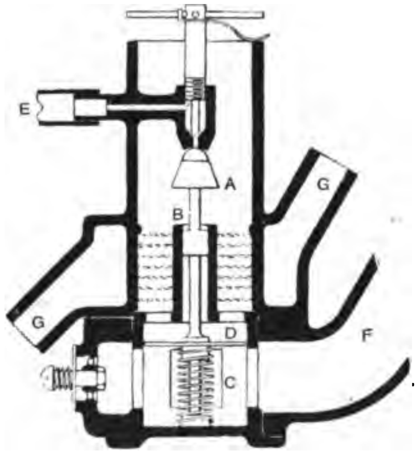


Fig. 92.—Friedman Carburetter.

Atomising carburetters are the most commonly employed. They have the advantage of being less cumbersome than the others, giving more uniform combustion, and not leaving any useless residue, the petrol spirit being vaporised completely as soon as it is brought into contact with the air. These atomisers have the inconvenience, however, of being more delicate, of often necessitating at starting the use of hot air, which in the case of motors employing electric ignition cannot always be obtained, and there is, in some, the necessity during a journey, after a stoppage of any length of time, of cleaning the pipes to remove the cold petrol spirit; this latter involves the loss of a little liquid, but the loss is not to be compared with that caused by clearing out residues from carburetters of the two other types.

The old Daimler-Phœnix carburetter is represented by Fig. 93. The petrol spirit arrives from the main tank by the passage N, and passes through the wire gauze O, which stops any solid particles it may contain, into the receptacle A. As soon as it has there attained the level of the top part of the nozzle J, through which it enters chamber H, the float B lifts the counter-weight E; now the rod D, being no longer held up by them, drops and presses the valve C against its seat; the flow of petrol spirit is interrupted, and thus the liquid is always flush with the top of the nozzle J. When suction occurs in M, the current of air arrives through F, and the petrol spirit emerges from J. The jets of air and spirit break against the mushroom K and mix intimately. A variable proportion of pure air, to bring the mixture to an explosive state, can be admitted by the lantern L. To clean

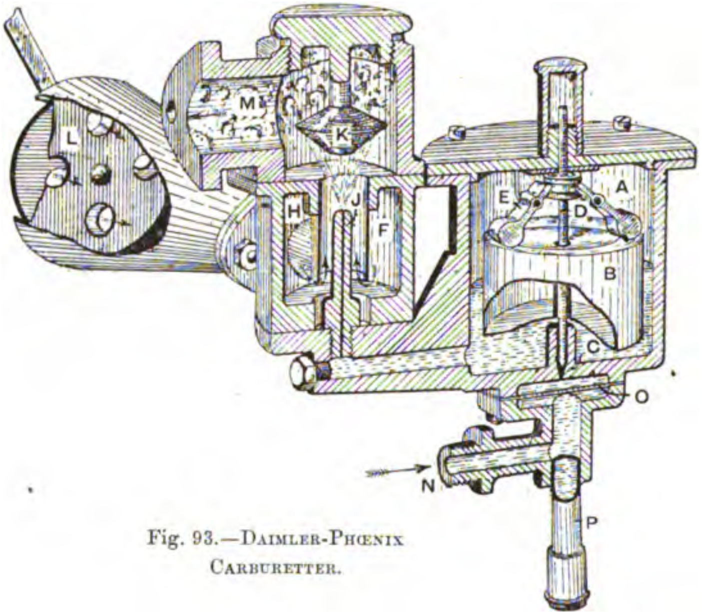


Fig. 93.—Daimler-Phœnix Carburetter.

the carburetter it can be emptied by a pipe P, closed with a screw cap.

The new English Daimler carburetter, shown in section by Fig. 94, has an unusually large float-feed chamber A. Petrol spirit enters by pipe B and passes to the jet C, which has an internal needle valve adjustable by means of the hand wheel D. The inverted cone E is easily removable, being fixed on the bayonet-joint principle. The auxiliary supply of air is admitted by the inlet F to the already formed explosive mixture, which then passes through the main supply pipe G to the motor. A water jacket H surrounds the mixing chamber; and the air drum, formerly a part of the Daimler carburetter, is not now used.

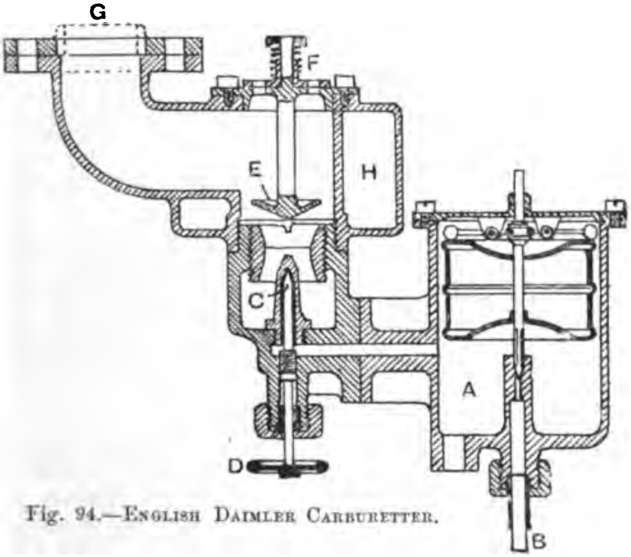


Fig. 94.—English Daimler Carburetter.

The Minerva bicycle new carburetter appears to be a modification of the Daimler-Phœnix device; minor differences are that the spirit is sprayed into an inverted conical chamber with stepped sides, the hollow spraying cone, also stepped, containing orifices through which the mixture passes to the motor feed pipe. The needle-valve stem projects through the top of the float chamber, as in the above, but it is not cased in, so that it can be raised and the carburetter flooded if this course should be necessary at starting.

Figs. 95 to 97 show the de Dion-Bouton carburetter as used on cars, it being totally different from the tricycle carburetter shown by Fig. 165, p. 184, and described on p. 87. The tube t admits air into a bronze body A, the tube t¹ taking the carburetted air to the motor. The body has a removable bottom, and surplus spirit flows through a hole drilled in it. B is a cylindrical valve turning in body A, regulating the air supply, and terminating at its lower end in a tube of smaller diameter, surrounding the nozzle D for part of its length; a prolongation of its upper part receives the adjusting lever I. C is an annular brass float composed of two concentric shells united by flanged and soldered heads, and D is a brass nozzle through which the spirit issues. E is the petrol admission pipe, serving also as a guide for the automatic valve, and at its lower end is a removable cap b, and on this rests a spring supporting a metal gauze strainer which arrests impurities in the spirit. Above the cap is the pipe leading from the petrol spirit tank. F is an adjustable admission

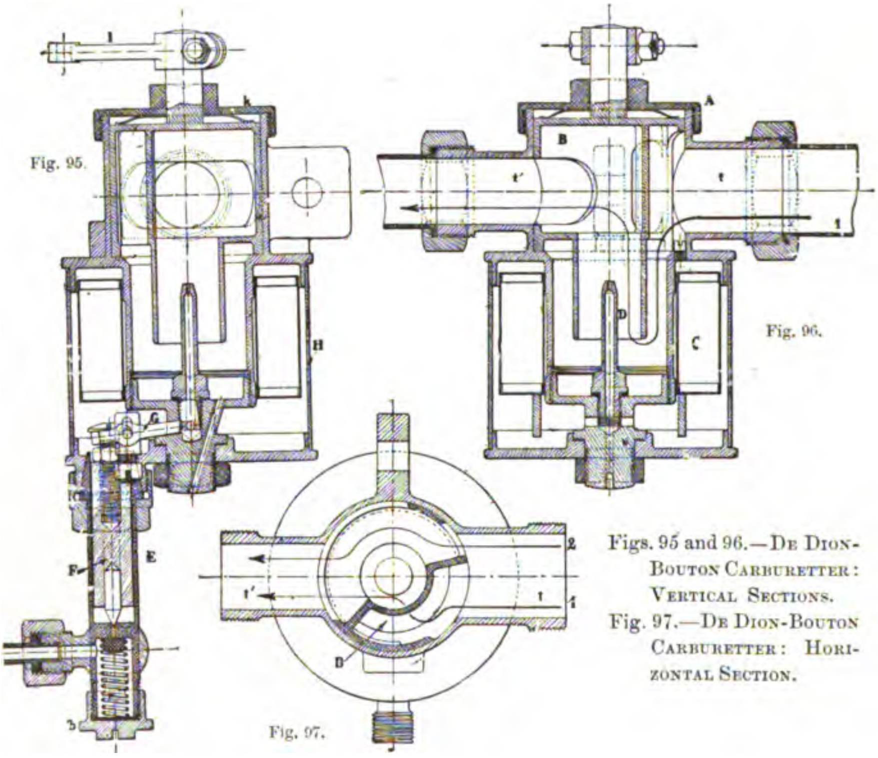


Fig. 95.

Fig. 96.

Fig. 97.

Figs. 95 and 96.—De Dion-Bouton Carburetter: Vertical Sections.
Fig. 97.—De Dion-Bouton Carburetter: Horizontal Section.

valve for petrol; it is composed of a brass rod with four longitudinal grooves for permitting the flow of the spirit, and its lower end has a nickel needle-point, whilst its upper end is drilled and tapped to receive the adjusting screw locked by a check nut. By means of the double-armed float lever G, the petrol supply to the float chamber is cut off automatically, the float resting on the long arm transmitting its upward force to the valve suspended from the short arm; in the illustrations this valve is shown closed. H is a float chamber composed of a brass tube united with the main casting A, and soldered to a bronze bottom. I is the operating lever, and K is a screw cap retaining the valve B in chamber A.

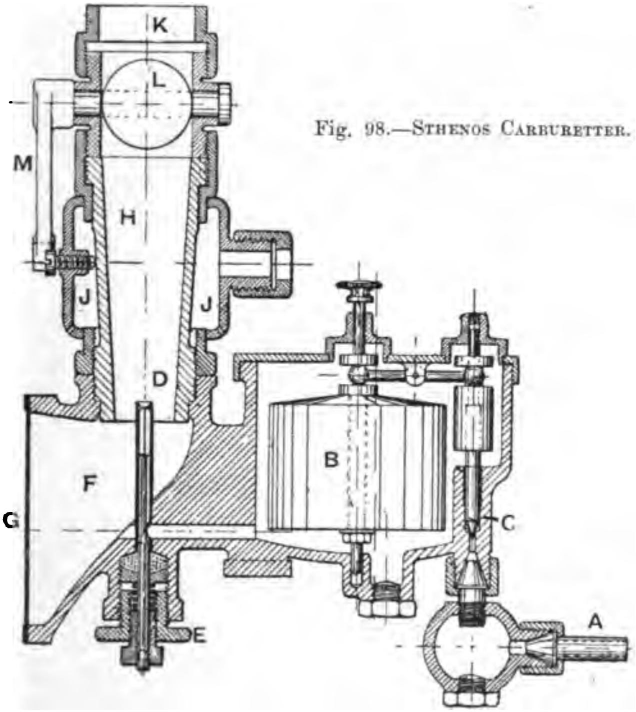


Fig. 98.—Sthenos Carburetter.

The Sthenos carburetter shown in section by Fig. 98 is used by the Decauville and other cars. The spirit arrives by A and passes into the chamber containing float B, the mechanism regulating needle valve C being clearly illustrated. The spirit is sprayed from pipe D, regulated by turning screw plug E, and it is then taken up by the air, which is brought through F, being filtered through gauze

G. The cone H tapering by 7 degrees is exhaust-jacketed at J, and this causes a very quick formation of the mixture, which passes to the motor through K, its amount being regulated by a disc, L, below K, controlled by lever handle M. There are modifications of this design, in some of which the spirit is delivered to the top of the float chamber, where it is filtered through gauze.

A very well-known carburetter is the Longuemare, and Fig. 99 illustrates a two-year-old type, suitable for either methylated spirit, carburetted spirit, or petrol spirit. This type was preceded by others differing in many important points from the present. The liquid passes through pipe I and past conical valve H to the point of arrival F in the constant-level receiver A containing the float B; J is the cleansing plug, E a spring piston, C the top of the receiver, and D the screw cap or plug. From the receiver the liquid flows to the actual carburetter through the regulatable screw valve f L, the liquid being driven into the cavity M underneath plug Z, and thence through a dozen small vents N into the air chamber K; a supply of fresh air coming through the pipe X carries the spray upwards. The carbu-

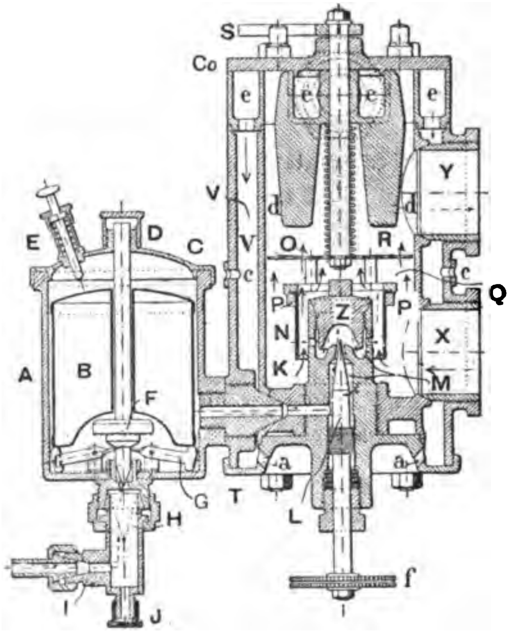


Fig. 99.—Longuemare Carburetter.

retting key S having been opened, the vents P become more or less uncovered, and the air and pulverised liquid pass through Q, and their intimate mixture is assured by the perforated disc O and by circulation around the radiating blades d in the gas chamber R, the mixture being delivered to the motor cylinder through pipe Y. The radiating blades are heated by the exhaust gases which flow into space V. Co is the cover of the carburetter, and e e are passages for exhaust gases. When methylated spirit is used alone, not admixed with petrol, it is necessary to heat the carburetter before it will start working; afterwards the hot exhaust gases keep it warm. The preliminary heating is done by uncovering the vents c, inserting through a some cotton waste soaked in alcohol, and lighting this in the space V.

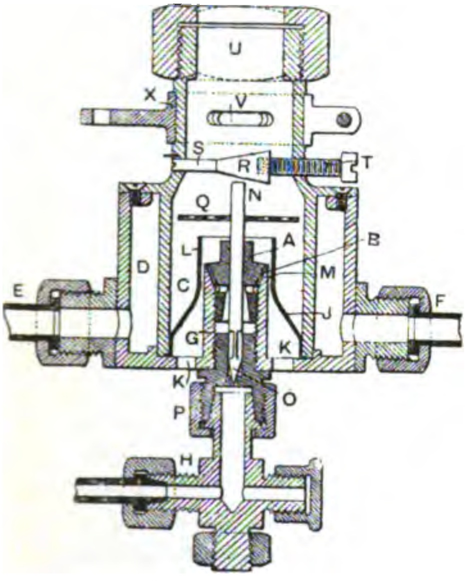


Fig. 100.—Longuemare Carburetter (New Type).

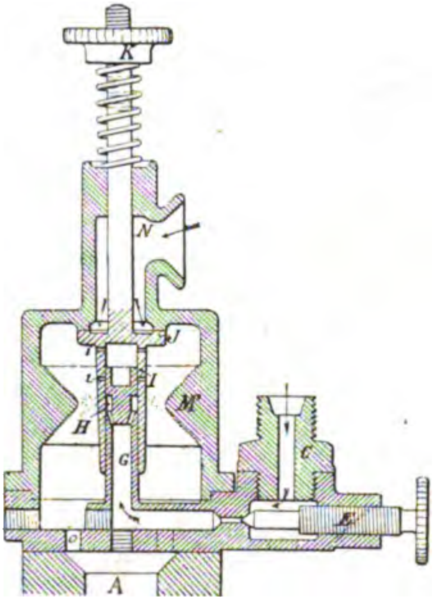


Fig. 101.—Chauveau Carburetter.

The Longuemare carburetter (patented in October, 1902, by Messrs. Fernand, and Georges Longuemare) bears hardly any resemblance to that described above. It is claimed to give precise regulation both as regards the quantity and proportions of the mixture, and as it may have possibly as big a vogue as the former Longuemare devices a detailed description of it is here given. Fig. 100 is a vertical section of the carburetter. The mixing chamber C is exhaust-jacketed at D the gases coming from the motor through flexible tubes E F. In the centre of the chamber C is the petrol supply device A, in which are holes B for squirting the petrol. A is mounted on tube G, to which the spirit is supplied in much the usual manner by the lower tube H, N being the spindle of the needle valve O P. A sleeve or tubular partition with enlarged base J, is secured in the mixing chamber so as to cover the air inlets K; and its upper part L extends above the petrol sprayer A, and in the annular space M thus formed the air admitted at K is mixed with the spirit, the extension L assisting the mixing. The perforated disc Q on spindle N serves as a baffle and makes the mixture more intimate, and the charge passes to the motor through the neck U. With regard to the regulator, passing through the neck is a rod S, with a wedge or cone R, and screw T. This screw, it is clear, determines the position of the cone, which in turn forms an abutment determining the height to which the needle-valve spindle N shall rise. Thus the amount of spirit admitted is controlled easily. The auxiliary air required comes through ports V in the neck U, regulated by a perforated ring, X. In operation the suction of the motor raises the disc Q, and consequently the needle-valve spindle N. Spirit is squirted out through the orifices B simultaneously with the suction of air through K. The rest of the operations have been made clear already. By reason of its few moving parts this carburetter is simple, and it remains for experience to show whether its efficiency is greater than that of the old forms.

In the Chauveau carburetter (Fig. 101) there is no auxiliary feed tank; the petrol spirit arrives directly from the main tank through a pipe fixed on the branch C. Its entrance into the apparatus is regulated by the screw needle valve E, and it ascends the central tube G, which is shut at the top part by a plug in which there are holes terminating at the circular neck H. Outside the tube G slides casing I, with openings *i i*, and solid with the valve J, the rod of which is prolonged outside the apparatus, and rests by its nut K on a spiral spring, which presses the valve against its seat. The fitting of the casing I on the tube G is watertight. When suction of the cylinder occurs at A, the valve J falls, and air, admitted at N, passes through it. At the same time the orifices *i* move to opposite the chamber H; and if E has been opened, the petrol spirit issues at *i*, and breaks against the rough truncated cone-shaped sides M^1. The finely divided spirit mixes with the air, and all passes through orifices *o* into the cylinder, and during its passage it can be mixed further with pure air by means of a special valve.

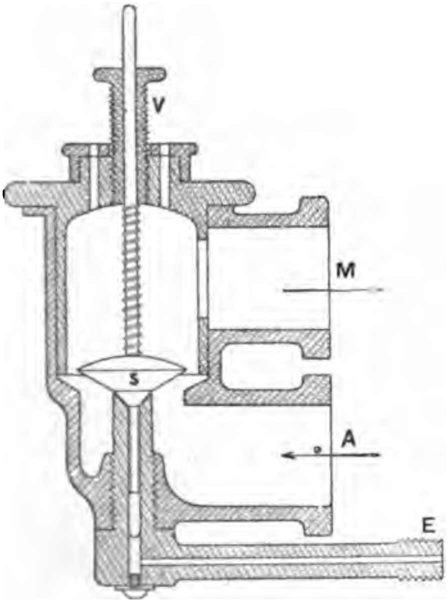


Fig. 102.—Gautier-Wehrlé Carburetter.

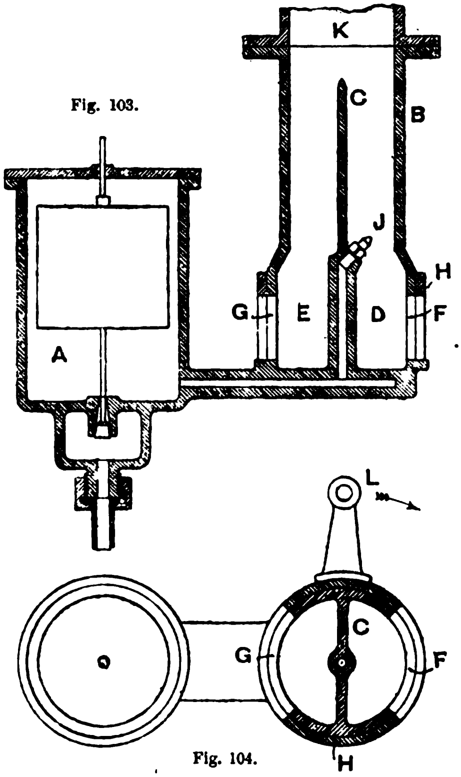


Fig. 103.

Fig. 104.

Figs. 103 and 104.—Sections and Part Plan of Mors Carburetter.

The Gautier-Wehrlé carburetter is shown by Fig. 102. In this the petrol spirit from the main tank is admitted under a rather high pressure by the small bore pipe E, and emerges under a spraying cone, S, which forms the top part of the valve. The latter is regulated by the screw V and spring, so as to rise slightly under the influence of the motor's suction, and allow a little petrol spirit to pass. The hot air admitted at A meets the sprayed spirit, and all is mixed with the proper quantity of cold air, which comes through orifices made in the lid of the mixing chamber, these orifices being more or less uncovered by a regulatable cap. The charge passes to the cylinder through M. This carburetter is believed to be abandoned.

The new Mors carburetter differs almost entirely from the old one, in which the spirit fell through an inverted cone having a grooved surface. The new device is shown in vertical section by Fig. 103, and in plan and part section by Fig. 104. The float feed is much as usual, and the spirit passes from the chamber A to the eccentric nozzle J, where it impinges on the cylinder wall B. The partition C divides the cylinder into two parts, D and E, and at the bottom of each part is an opening, F and G respectively; a perforated sleeve, H L, governs these openings, and is under the driver's direct control. The air entering at F is duly carburetted in part D, and the mixture is diluted by the air which enters G and passes up E. The mixture then goes straight to the motor through pipe K. This, at least, has the merit of simplicity.

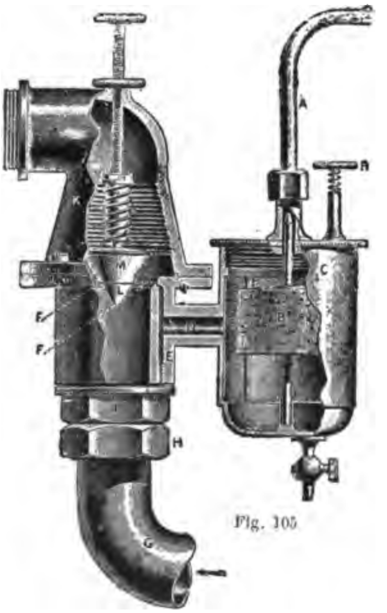


Fig. 105

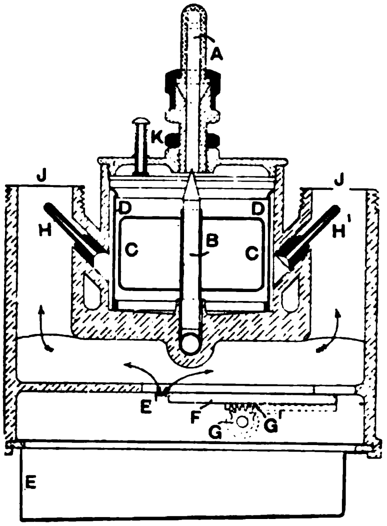


Fig. 106.

Fig. 105.—G. Richard Carburetter (Old Type). Fig. 106.—G. Richard's Carburetter for Four-cylinder Motor.

Another constant level carburetter is that of Georges Richard (Fig. 105), and in this the spraying action of the inrushing air is used to pulverise the petrol spirit by dashing it between the surface of an inverted cone M and the corrugated surface K of a containing passage. The air enters the pipe G, lifts the cone M, and passes through the inlet valve of the motor. By pipe A the petrol spirit enters chamber C containing float B, and flows through the passage D into the annular space E. Small holes F through the seating of the cone M lead into the space E, and the petrol spirit thus is fed into the air passage whenever the cone M is raised. I and H are union nuts.

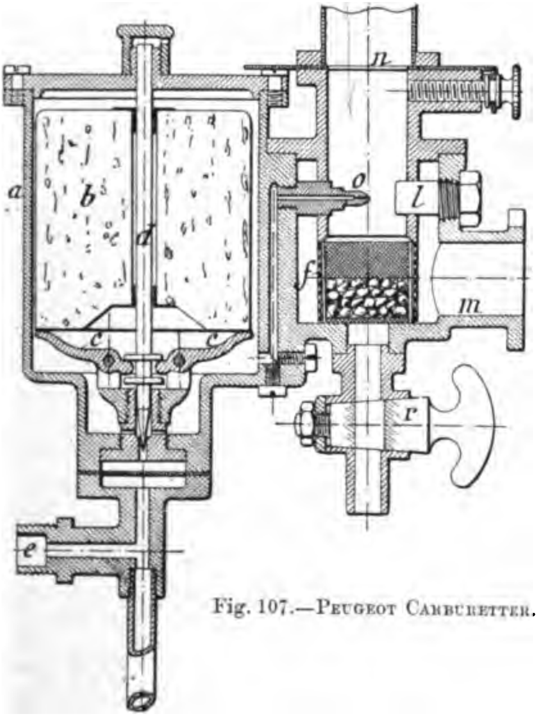


Fig. 107.—PEUGEOT CARBURETTER.

The new Georges Richard carburetter has a separate spraying nozzle for each of the four cylinders fitted on the 1903 40 h.p. car, the advantage being that each jet may be regulated to suit the requirements of each cylinder independently of the others. Fig. 106 is a sectional view of the carburetter, which is a box-like construction with a cylindrical float-feed chamber in the centre and the induction pipe connections to the four cylinders at the corners. Petrol spirit enters the float chamber D at the top through A, B being the needle valve, and C the float, and H H^1 the spraying nozzles. Air enters at the bottom through E, passes up through the orifice E¹, and goes through J to that cylinder in which the suction is taking place, carrying with it the spirit ejected from the nozzles H H¹. The size of the air inlet E¹ is regulated by the slide F, actuated by rack and pinion G¹ and G. By depressing the plunger K, the float also is depressed and the carburetter flooded.

The Peugeot carburetter is illustrated by Fig. 107. The petrol spirit enters it through pipe *e*, and runs into tank *a* as long as the cork float *b*, by resting on *c*, keeps the needle *d* raised. As soon as the float is sufficiently raised not to press on *c*, the needle *d* falls by virtue of its own weight, and closes the inlet. The apparatus is regulated in such a manner that the level in the tank *a* is maintained a little lower than the nozzle *o*, thus preventing the petrol spirit from overflowing into the carburetter chamber *f*. Under the influence of the motor's suction, the petrol spirit issues from the nozzle *o* against the atomising plug *l*; a current of air heated by burners then arrives through a tube situated above this air-current, following a direction perpendicular to the jet of spirit, owing to the deviation caused by a socket with baffles in combination with a wire gauze, which retains the fine parts of the

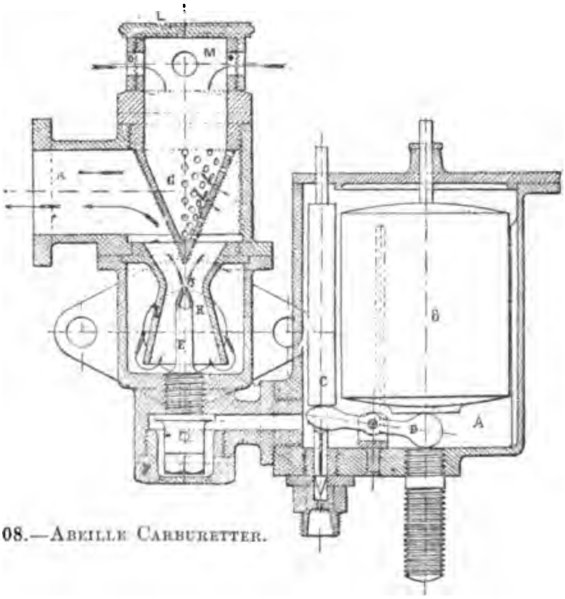


Fig. 108.—Abeille Carburetter.

non-vaporised petrol spirit, and assists the intimate carburetting of the air. The delivery of the petrol spirit remains constant. Shutters placed on each side of the tube which conveys the hot air render it possible to admit cold air to obtain a normal degree of carburetting; the movable diaphragm *n*, worked by a screw, also helps to modify the mixture of hot and cold air, and, in consequence, that of the carburetted mixture which is conveyed to the cylinders by pipe *m*. According to the quality of the petrol spirit and temperature of the air, the mixture also is varied by aid of the cold air cock *r*, placed below the carburetting chamber, and mainly intended to prevent excessive carburetting. At starting, the cold air inlet is shut, so as to admit nothing but the air heated by the burners. The only attention necessary is cleaning the filter when choked by the foreign substances removed from the petrol.

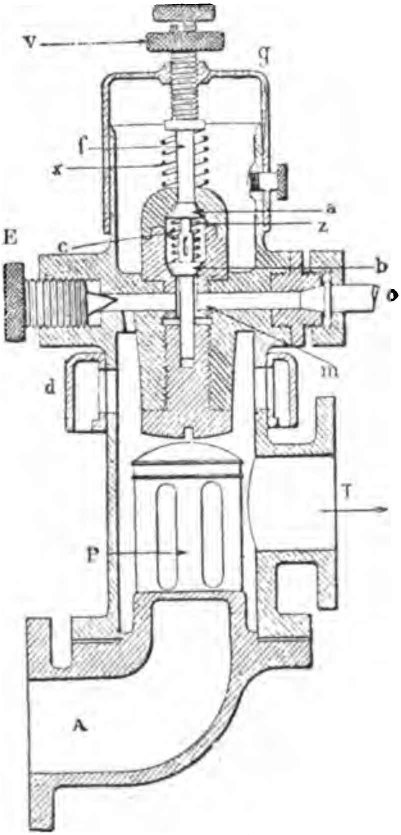


Fig. 109.—LEPAPE CARBURETTER.

The Abeille constant level carburetter (Fig. 108) combines the float-feed principle with a more or less perfect pulverising device, the spirit being kept at the level of the top of a small nozzle by a float-feed arranged in a neighbouring chamber. In the chamber A is a float, B, resting on one end of a lever, D, whose other end supports the spindle C, at the lower end of which is a needle valve through which the petrol spirit flows, the supply being automatic. Air enters by the tube H through the lower part of the converging passage, the throttled portion corresponding to the end of the pipe E, and the air carries with it a quantity of petrol spirit previously regulated by the size of nozzle orifice J. The mixture is thrown on the hollow cone G, pierced with a great number of small holes through which passes the additional supply of fresh air. For this purpose the cone G has a movable cap, L, containing four openings M, opened or closed by the rotation of the cap. The carburetted air passes to the motor through tube K. For cleansing or adjusting the nozzle J it suffices to unscrew the plug F, and to withdraw the pipe E by the lower part.

Fig. 109 represents one type of the Lepape carburetter. The petrol is brought by the pipe *m*, passing under valve *b* (normally maintained a little above its seat by its union with the valve *a* and the spring *z*) and fills the chamber *c*; *f* and *x* are the spindle and spring respectively of valve *a*. When suction of the piston takes place in T the hood G falls, and forces down the valve *a* into the chamber *c*, causing a certain amount of petrol spirit to overflow. The admission and emission of the petrol spirit are, moreover, regulated by the position of the hood on its screw, this position being maintained by the threaded nut V, and by the force of suction which can be decreased by allowing fresh air to enter by ferrule *d*. The petrol spirit falls on P, the lantern with wire gauzes through which the hot air comes from A. The mixture passes through T to the cylinder. E is a screw needle valve, which at starting is unscrewed to allow a little petrol spirit to fall through the opening *o*, on to the lantern P, and is completely removed to clean the spirit intake tubes.

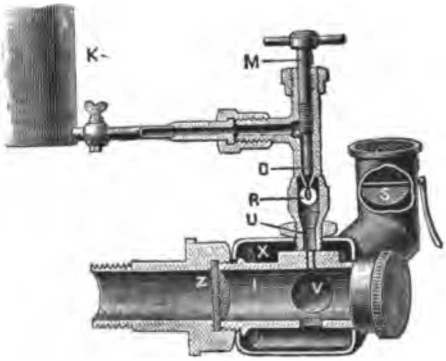


Fig. 110.—Loyal Carburetter.

In a recent type of the Loyal carburetter, Fig. 110, the petrol spirit contained in tank K flows around the needle M O in drops which can be seen through the opening R, and falls through orifices U into the mixing chamber I The air sucked by the motor arrives through pipe V mounted on the casing X, and furnished with a regulating valve S. The mixture thus formed is completed in passing through the wire gauzes Z, and then goes to the motor cylinder.

In the Bouvier-Dreux or Dorey carburetter (Fig. 111) the petrol spirit is kept at a permanent level in the tank B by the float C furnished with a needle D, which commands the opening of the inlet pipe, and a level indicator J; this level is established through channel E in the nozzle F at 1 mm. (0·04 in.) below its orifice. Around this nozzle are three spiral grooves which force the air sucked by the motor through pipe G to acquire a gyratory motion; at the same time, under the influence of suction, a small amount of petrol spirit issues from nozzle F, is agitated, and mixes with the eddying air. To make the mixture intimate the complemental air supply and the current of enriched air break against the vanes of two little turbines H H^1, situated in the chamber above the nozzle; these turbines turn very rapidly owing to the suction of the motor through a pure air inlet valve not shown in Fig. 111, but which is placed symmetrically as regards the pipe I, through which the charge passes to the motor. At starting, this air inlet valve is gradually opened until the best mixture is obtained. Air previously heated by the motor can be admitted through pipe G to aid the vaporisation in cold weather.

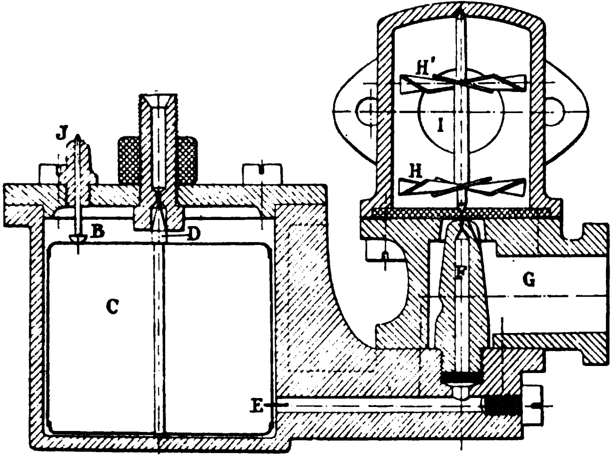


Fig. 111.—Bouvier-Dreux or Dorey Carburetter.

The Jupiter carburetter has points of similarity with the preceding, it having a permanent level by float and helicoidal grooves around the petrol spirit intake nozzle, and there are palettes in the mixing chamber.

The Huzelstein carburetter (Fig. 112) is known favourably on the

Continent, and in it the supply of petrol spirit is determined by a spring-controlled needle-valve, actuated by atmospheric pressure when a partial vacuum is created in a closed chamber which is in communication with the motor cylinder during the piston's suction stroke. A cylindrical chamber is closed at the upper end by a cap containing holes, a a, which admit air, and affixed axially to this cap is a stem or tube in connection with the supply pipe E, leading from the petrol supply tank situated above. The admission of petrol is controlled primarily by the screwed needle-valve, which can be given any desired opening, the amount of this being indicated by a finger attached to the handle moving over a graduated disc. Within the cylinder is a valve attached to a spindle and held up to its seat by a spring upon the spindle. The upper part of the cylindrical chamber is surrounded by a jacket which communicates with the exhaust, the lower part being in communication with the motor cylinder during the intake stroke. The bottom cap of the cylindrical chamber is perforated and fitted with a rotating disc, so as to vary the area of the air inlet holes and in consequence the amount of air admitted. The action is thus: The upper needle-valve is opened by turning the handle to admit a certain quantity of petrol spirit; on the suction stroke of the motor the middle valve drops, opening the needle-valve, and also by the partial vacuum thus formed, allowing air to enter at a a. The air and petrol, entering the upper part of the chamber which is heated by the exhaust gases, are heated quickly and the

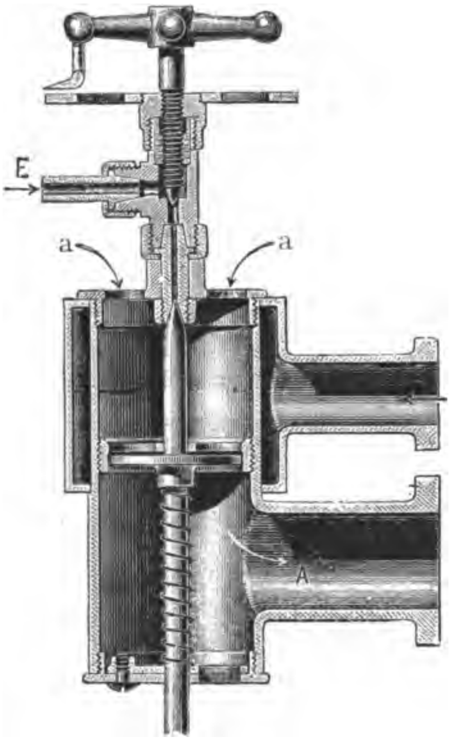


Fig. 112.—Huzelstein Carburetter.

petrol spray is vaporised. A further supply of fresh air is obtained through the orifice in the lower part of the chamber, the charge passing to the motor through A. This carburetter acts well when new, but the tapping action of the pointed pin in the bottom of the fire tube has a tendency to cause leakage and the ultimate destruction of the oil outlet.

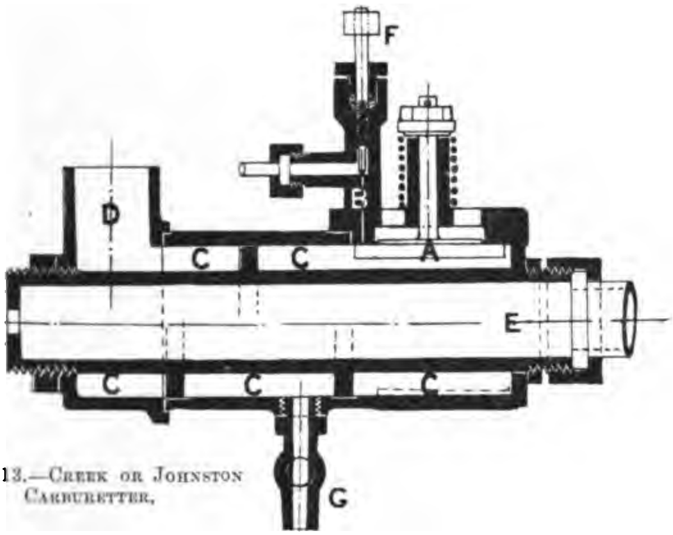


Fig. 113.—Creek or Johnston Carburetter.

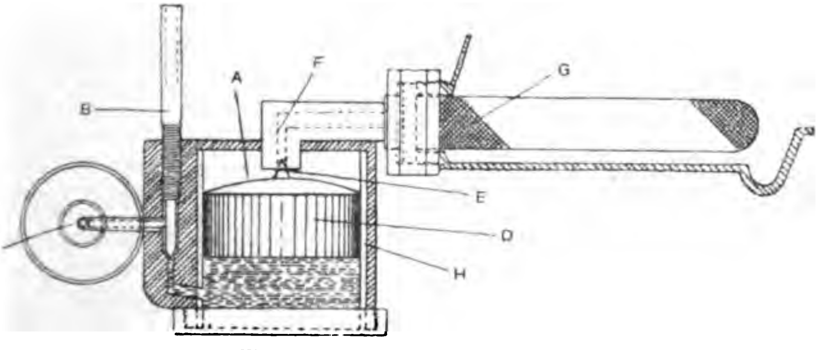


Fig. 114.—Duryea Carburetter.

The Prétot carburetter is a double chamber, having adjustable orifices, for the admission of air; within the inner chamber is a bell-valve which has a stem terminating in a needle-valve. The action is as follows: On the suction stroke the bell-valve rises, and petrol spirit flows up through the needle-valve and under the lips of the bell-valve; then it mingles with the air in the mixing chamber, and the mixture passes to the motor cylinder.

The Creek or Capel carburetter, which is known also as the Johnston, is shown in section by Fig. 113. The spirit is fed to a needle-valve B regulated by F, and an induction valve A normally prevents its flow into the spiral chamber C around tube E; through this tube is led part of the exhaust gases. The induction valve A opens automatically at each suction stroke of the piston, and in so doing allows the spirit to pass; this is taken up by the entering air, and an intimate mixture is effected on its way to the motor through pipe D. G shows a drain cock. This resembles the Martha device, p. 148.

The Duryea carburetter is a float-feed device, and very simple in design. The petrol spirit is gravity fed by the tank through gauze G to the needle-valve F E, directly operated by float D, kept central by guides H. This is the simplest possible float regulation. The needle-valve B regulates the admission to mixing tube C, where the spirit mixes with the air, of which there is an adjustable supply. The arrangement is unusual, but appears to be quite efficient.

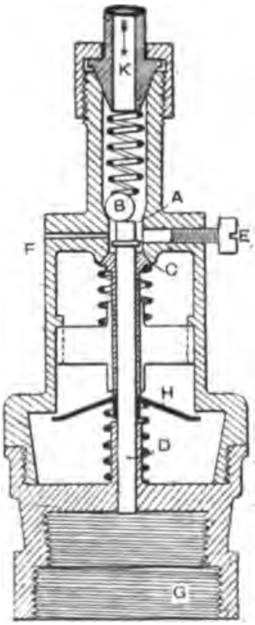


Fig. 115.—Knapen Carburetter.

The Knapen carburetter (shown in section by Fig. 115) has not yet been much used, it is thought, but it presents a means of regulating the flow of spirit that is novel. The regulator comprises two valves, one a ball-valve B, working in chamber A, and a valve C; spirit enters at K; through C passes with easy friction a rod D, carrying a stop, the little collar below B, and a disc H, the latter closing the air passage of the carburetter. The size of chamber A is regulated by screw E. All the valves are maintained in position by means of springs as shown. The device works as follows. It is attached to the motor suction pipe at G, when the suction phase begins, and owing to the consequent reduction of pressure the disc H is forcibly attracted, carrying with it the rod D; then the ball-valve B falls, thus isolating in the chamber A an exactly predetermined quantity of spirit. The rod continuing to descend, its collar stop displaces valve C, and permits the spirit to escape and mingle with the air sucked in. A small quantity of air is at the same time sucked in through hole F, and serves to efficiently vaporise the spirit.

In the float-feed spray carburetter employed on the 10 h.p. Autocar tonneau, an American vehicle, there is an arrangement for automatically varying the richness of the mixture while throttling the inlet on the motor. The spraying chamber is in two unequal parts, and the air enters near the bottom and passes into both of them. In the centre of the larger chamber is the spraying nozzle. A cup with a central spindle adapted for turning it is mounted in the upper portion of the carburation chamber, the bottom of the cup resting on the vertical partition and being cut out so as to form an opening projecting over each side of it. Regulation is effected by turning the spindle controlling the cup. The parts are so proportioned that when turned to restrict the total delivery of gas, the size of the fresh air opening relative to the mixture opening is reduced also, the richness of the gas thereby being increased. The carburetter is warmed by leading the air-inlet pipe under the motor water tank, which gives off sufficient heat after the motor has been running for a short time.

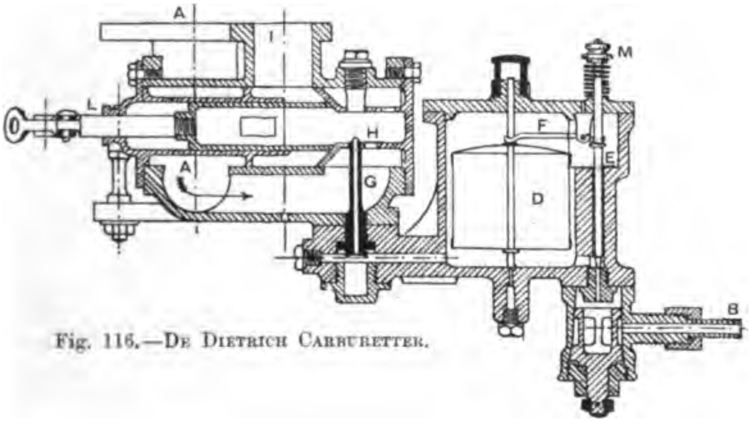


Fig. 116.—De Dietrich Carburetter.

The De Dietrich new carburetter provides very simple means of regulating the amount of carburetted mixture supplied; in other respects the device is constructed on ordinary lines. Fig. 116 shows a section of the carburetter; the air comes through A, and the petrol spirit through B. The needle-valve with stem E is regulated by nut and spring M, and is controlled by the float D by means of the forked lever F. The spirit is ejected from G, the air rushing from A through H intimately mixes with it, and the charge passes to the motor through pipe I on the pulling out sufficiently of a throttling or governing tube at the end of lever L, controlled by the driver's pedal.

A sliding sleeve also is employed as a throttler in the new Richard-Benz carburetter used on the Benz 1903 cars.

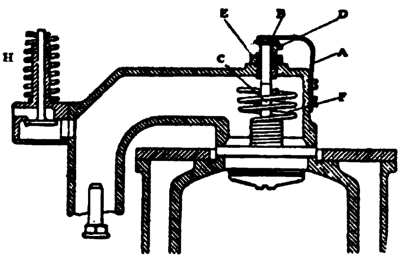


Fig. 117.

Fig. 117.—Bradley-Pidgeon Induction and Auxiliary Valves.

Figs. 118 and 119.—Singer Bicycle Carburetter.

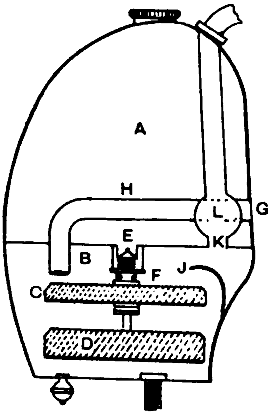


Fig. 118.

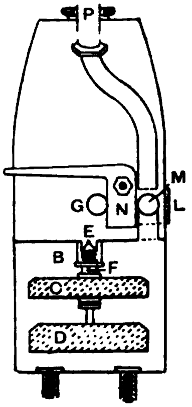
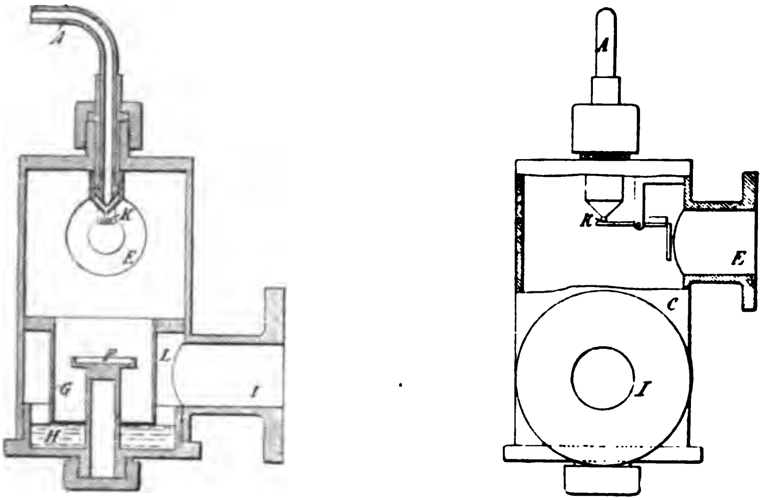


Fig. 119.

The Bradley-Pidgeon carburetter is mentioned in a paper read before the Institute of Mechanical Engineers by Captain C. C. Longridge, who notes that manufacturers have recognised the disadvantages of the "aspiration" carburetter, in which the spirit is drawn from a jet communicating with a constant level source of supply; owing to the force of the piston suction varying with the motor speed, the supply is faulty, rich charges being obtained when the motor races, and poor charges when it slows down from overload, the reverse of what should be the case. Messrs. E. F. Bradley and W. R. Pidgeon attempt to so adjust the supply that the lower the speed the richer is the mixture, the object being to get the maximum power at whatever reasonable speed the motor may be running. As it is difficult to adjust so small a thing as the spirit jet hole, a small air-spring valve (H, Fig. 117) is inserted in the air-pipe between the carburetter and the induction valve. The auxiliary valve opens wider and wider as the motor speed increases, closing again as it decreases, thus decreasing or increasing the suction in the spirit jet. This device has been tried before. In Fig. 117, giving a section of the motor head, induction valve, etc., on the Bradley-Pidgeon principle, A is the induction valve recoil spring, B the valve stem head, C the valve stem, D adjustable guide to the valve stem, E lock nut to D, F main induction spring, and H the auxiliary valve already mentioned.



Figs. 120 and 121.—Gautier Carburetter.

The carburetter used on the Singer motor bicycle (*see* p. 760) is a compromise between the surface and spray types, and in it is avoided the necessity, present in earlier forms, of continually adjusting the air admission lever; in the first Singer motor wheel the rider had to dismount for this purpose, though only occasionally. Figs. 118 and 119 are side and end views of the modern tank A and carburetter B, separated by a horizontal plate on which is mounted a three-way throttle valve for the chimney H, petrol valve E, and mixture pipe K to pass. The spirit passes from tank to carburetter through needle-valve E, and squirts out through the tiny holes F F in the valve mount on to a fixed cork block C, over which it trickles to the bottom of the carburetter. When it rises sufficiently the lever fixed to the lower block of cork D closes valve E, and stops the supply of spirit. Air is brought from G through chimney H, and as it mixes with the vaporised spirit it rises through orifice K into the combined throttle and mixing valve L, where additional air mingles with it according to whether the opening M is fully open or partly closed by shutter N. This shutter has connecting rods operated by a lever near the rider's hand. The mixture passes to the motor through P. The baffle J prevents the spirit splashing out direct from the bottom of the carburetter to the opening K.

Certain carburetters unite in one appliance the peculiar features of the three classes above described, but of this fourth class only one device—the Gautier carburetter employed for David cars—will be mentioned. It is illustrated by Figs. 120 and 121, in which A is the inlet for the petrol spirit, whose delivery is regulated by the double diaphragm, which prevents the section of the flow of the petrol spirit from being enlarged appreciably by contact with the valve K, which rests only on the exterior diaphragm. Valve K, which regulates the delivery of the petrol spirit, opens at the proper instant, under the action of the current of air caused by suction. The petrol spirit falls on the saucer F, and thence into the tank H, above which is the pipe G, supported by a ring at such a height that only its lower edge is in contact with the petrol spirit. The air sucked through I circulates in chamber L, and makes a surface contact with the petrol spirit in the saucer F, the mixture then passing to the cylinder through E.

In the carburetters hitherto described the petrol essence arrives simply by gravitation, whereas in some others mechanical devices are employed, these being known as mechanical distributors. Thus, in the Klaus carburetter, the petrol spirit is injected by aid of a pump, which is worked by the motor cylinder exhaust valve cam, and driven back after each piston stroke by a spring.

The Henriod distributor-carburetter is thus named because it mechanically distributes at each suction of the cylinder piston a volume of petrol spirit; this volume is fixed by regulating the apparatus, and does not depend upon the temperature at which carburetting is effected, contrary to what occurs in ordinary carburetters. In the cylindrical body of the apparatus are two valves, normally pressed upon their seats by springs; the top screwed extremity of one valve rod has a nut-disc, into which a regulating screw enters vertically. The second valve has a hollow rod, which can slide between the solid valve rod and a cylindrical casing. In the casing a little below the second valve is a circular compartment, which is in permanent communication with the petrol spirit tank by means of an orifice. As soon as suction is produced in the cylinder, the valve with the solid rod falls, alone at first; and then, when the screw referred to comes into contact with the second valve-rod (and contact takes place more or less rapidly, according to the depth the screw has been sunk in the nut at the time of regulating), the two valves move together. The combined two valves stop as soon as the nut-disc of the first touches the cylinder below. Whilst the second valve is raised from its seat, the petrol spirit flows into circular grooves made in the cap of the same valve. There it is in contact with hot air admitted by a first row of orifices. The mixture passes to a chamber underneath, where is added a suitable amount of fresh air. The amount of liquid which enters the apparatus each time is thus regulated by the nut-disc and its screw.

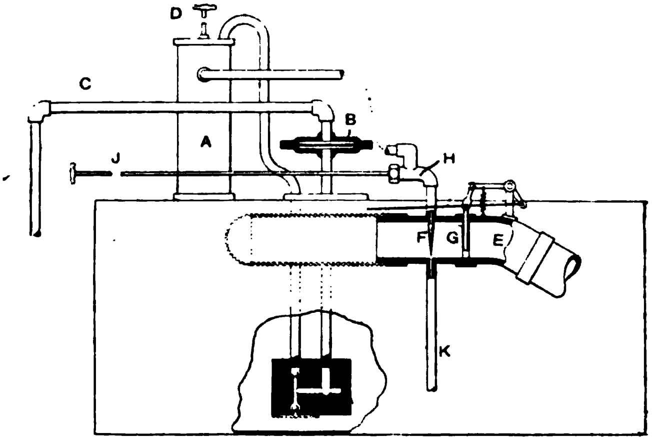


Fig. 122.—Oldsmobile Carburetter.

Like the apparatus just described, the Brillié distributor mechanically distributes petrol spirit, but instead of introducing a fixed quantity each time and preparing the carburetted mixture with it as an ordinary carburetter does, it measures each time, under control of the regulator, the requisite liquid for the charge, the mixing in air being effected in the pipe from the distributor to the cylinder, and in the cylinder itself. Quantities of the petrol spirit are measured in the Brillié distributor as follows:—A single plug, with equidistant pockets on the circumference, turns in a seat communicating with the petrol spirit tank. Each pocket, when filled with liquid, is brought, by rotation of the plug, opposite an orifice which communicates with the motor by an orifice and a strainer. Rotation is caused by a pawl-and-ratchet gear which governs the motor shaft by a connecting rod of the regulator. If the regulation speed is exceeded, a tripping device stops both rod and distributor, and the supply of petrol spirit ceases. By giving more or less play to a spring, a lever allows the motor to perform a greater or lesser number of revolutions (250 to 1,000 per minute). Thus, the amount of petrol spirit for each cylinder charge is just what is required for uniform carburetting, complete combustion, and the avoidance of odour. This, at least, was the inventor's object, and time will tell whether he has fully succeeded. The Brillié carburetter may be described as a distributor with which carburetting is effected in the suction chamber. The application of the device to the Gobron-Brillié two-cylinder petrol motor is described on pp. 245 to 247.

The Oldsmobile carburetter is an ingenious American contrivance, designed with a view to having the petrol spirit tank below the level of the mixing chamber, whilst at the same time ensuring the conveniences of a gravity feed. A small vertical cylinder A, Fig. 122, extends from the bottom of the tank to a point above engine level. A diaphragm pump B supplies spirit from the tank to an annular chamber in the top of cylinder A, and a pipe C from the upper side of B is connected to the enclosed crank chamber of the single-cylinder horizontal motor, and the vibrations of the diaphragm are produced by pressure variations in the crank chamber. Cylinder A contains a lifter connected by a rod to the handle D for starting the engine before the diaphragm pump can work. Raising the handle causes the annular space or reservoir before mentioned to be filled with petrol, which then passes through a sloping pipe to the intake E, where it dribbles down an inverted cone F, and is caught and vaporised by the inrushing air. The intake is controlled by a throttle G, and the flow of spirit is regulated by a needle-valve H with rod J. The pipe K conducts back to the tank any unvaporised spirit dripping from the cone immediately above it.

The Krebs carburetter of the latest type employed on the new Panhard and Levassor cars varies the quantity of auxiliary air drawn into the carburetter for the purpose of diluting the charge automatically according to the suction of the motor. To effect this, a sliding sleeve is fitted inside a cylinder, into which the auxiliary air is drawn through holes in the cylinder wall. Normally the sleeve closes the holes, and is connected with a piston and diaphragm in such a manner that the formation of a partial vacuum beneath them displaces the sleeve, and admits air in quantity depending upon the degree of vacuum obtained. The current of air which passes round the spirit nozzle and sprays the spirit is maintained practically independent of the general air supply. This overcomes the disadvantage of the ordinary carburetter, in which, when the motor runs very slowly, or when the throttle valve is nearly closed and the piston suction is correspondingly less, the amount of spirit injected into the mixing chamber is reduced. By diminishing the auxiliary air supply, however, the vacuum in the mixing chamber is kept constant, and the richness of the mixture remains the same. The new carburetter, also, has its mixing chamber jacketed with the motor cooling water. The object gained is a constant degree of carburation at all speeds, each active piston stroke developing the same amount of power, and the total power of the motor consequently is directly proportional to its speed. Also, carburation can be kept at its lowest possible limits, and it is perfectly automatic and independent of variations in the atmospheric temperature. The carburation is always good. The usual dash-board adjustment for additional air and a special hot-air feed are not needed: the warming of the mixing chamber with the motor jacket water maintains a constant temperature. The motor can be run at a very low speed without lowering its efficiency. For instance, as the *Automotor Journal* states the case, if the change-speed lever is put on the third speed, which ordinarily might give a speed of 50 km. (31 miles) per hour, and it is desired to run at only one-fifth of that speed, the speed of the motor is reduced to one-fifth, say from 1,000 to 200 revolutions per minute; of course, the total output is diminished, but the power of each stroke remains the same. The new Krebs carburetter, then, goes far to supplying one of the chief needs of the petrol motor—flexibility.

A detailed description of the new Krebs carburetter, which is employed on the Panhard and Levassor cars, may now be given. Fig. 123 is a general view, and Fig. 124 may be regarded as a mere explanatory diagram, not drawn to scale, showing a section of the carburetter. Petrol spirit, E, comes from the tank attached to Z, passes through filter I (access to which is by unscrewing cap N), and rises into the float-feed chamber B, maintaining a constant level in the nozzle pipe D. The motor sucks through tube A a volume of air, and this causes the ejection of a quantity of petrol through the nozzle; the quantity ejected is determined by the degree of vacuum produced, and is adjusted to give proper carburation at a speed of 200 revolutions per minute when no auxiliary air enters the mixing chamber, C. The mixture passes to the motor through U. For speeds above that mentioned, the additional air enters by the apertures M (shown clearly in Fig. 123), and joins the mixture. The degree of vacuum produced in the carburetter by the intake stroke, due to the displacement of the piston, bears direct relationship to the motor speed, apart from the effect of the throttle-valve G; and it is this relationship

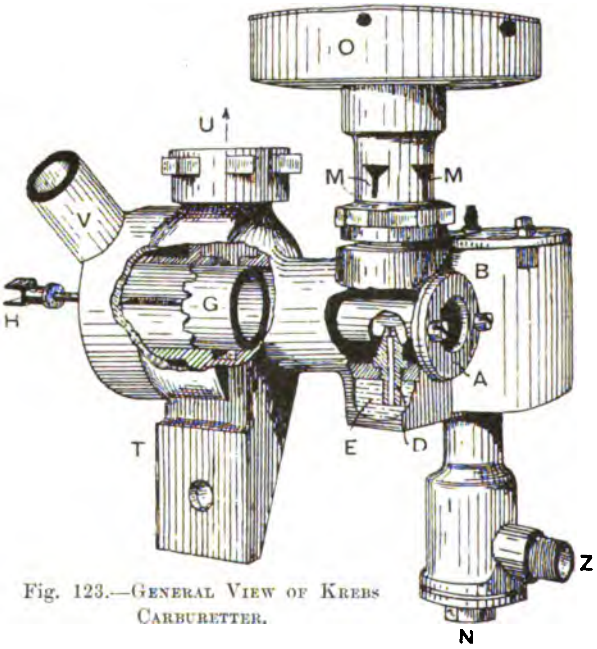


Fig. 123.—General View of Krebs Carburetter.

which controls the degree to which the additional apertures M open. To effect this, there is a valve K, resembling that employed for controlling the motor speed. The ordinary horizontal throttle G, controlled by a centrifugal force governor, simply regulates the admission of the charge to the motor cylinder; at one end it has a number of V-shaped notches for the purpose of gradually opening the inlet, and permitting the supply of gas to pass into the intake progressively; this arrangement has nothing special about it, and Fig. 124 shows its construction sufficiently. The driver can as usual regulate the action of the opposing spring in the throttle independently of the governor action. At starting, the governor keeps the throttle fully open, and a full charge enters the cylinder. In a second or so, the governor comes into play, and through rod H operates the throttle so as to close the intake. The throttle-valve, then, is a governor-operated cock, further controlled by the driver. The vertical auxiliary air-valve K is controlled by the amount of vacuum produced in the carburetter, and its movements correspond more or less with those of the throttle; its controlling rod is surmounted by the large disc Q, mounted in case O by an indiarubber flexible diaphragm. The whole arrangement is air-

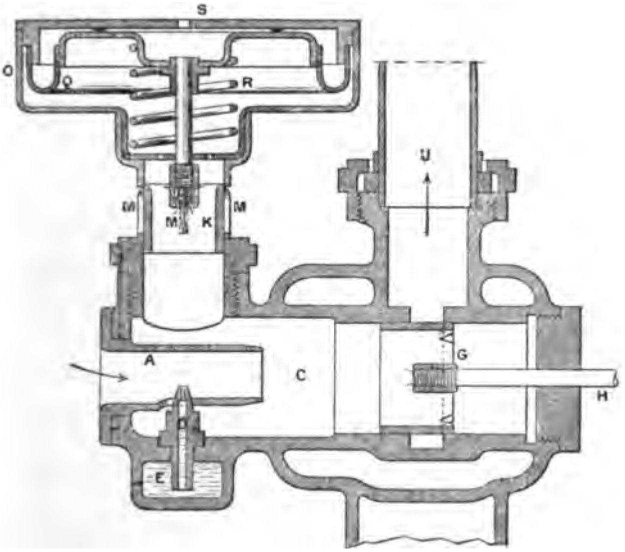


Fig. 124.—Section of Krebs Carburetter.

tight, but a hole, 2 mm. (·078 in.) in diameter, is made at S in the cover, so that when the disc Q is drawn in by the motor suction and retreats from the cover, the chamber between disc and cover is filled comparatively slowly with air which enters through the hole S; the volume of this chamber increases slightly, as a part of its walls is formed of the indiarubber diaphragm. Correspondingly, when the suction stroke has ceased, the air passes out from the chamber relatively slowly through S, when the spring R brings back the disc Q to its original position. This disc must be fairly large, so that valve K may move at every slight variation in the degree of vacuum produced; but the hole S must not be large, or the movement of the disc, when the apertures M open, would be too sudden and intermittent at high speeds, and the spring action would not be prompt enough, owing to the inertia of the parts. On the contrary, in the arrangement as it stands, the valve K is practically in unstable equilibrium, like the beam of a balance, one of its arms being subjected to the force due to the partial vacuum, and the other to the force of the spring. With the hole S made small, a brake or dash-pot effect is produced, this preventing hunting and vibration. Importance is attached to the shape of the apertures M, through which the additional air comes. Their form is claimed to be mathematically exact, and to have the effect of maintaining the admission and carburation constant and adequate, no matter what the variations in the partial vacuum may be. V is the hot-water connection, and T the attachment lug.

The convenience of having carburetters that could deal with heavy oils as well as with petrol spirit has been referred to by Captain Longridge. A number of combination devices for the double purpose have appeared lately, but experience is still wanting as to their efficiency. According to Captain Longridge, Russian oils are sufficiently pure to require no more preparation than atomising and vaporisation effected by an easy application of heat. Indeed, it appears doubtful whether even vaporisation is needed or mere spraying would not suffice. Mr. James Roots has found by experiment when oil is sprayed into a working cylinder that the essential thing is ignition, as the oil is fired as spray and is not vaporised, and that once the ignition begins the flame passes almost as rapidly through the particles of sprayed oil as through a completely vaporised and mixed charge. With American oils it might not be so easy to get satisfactory results without special vaporisers. These oils are "cut" differently, and contain waxy and resinous compounds that in long and continuous running would form deposits on the walls and valves. The conditions for successful use appear to be: uniform delivery of minutely atomised oil in correct proportion, high cylinder temperature, no condensation by contact with cool surfaces, and sufficient time for combustion. For alcohol, similar conditions, with higher compression, appear best suited.

For vaporising petroleum, which is much less volatile than petrol spirit, two extra aids have been employed; these extra aids were (*a*) the heat furnished by a petroleum lamp (or the heat produced by the working of the motor sometimes is used instead), and (*b*) the use of a pump which injects at each of its strokes the requisite amount of petroleum.

Modern methods of employing heavy oil in the place of spirit may be described briefly as (1) converting the oil into vapour outside the motor cylinder, which then may be said to work as an oil-gas engine having a lower output than if spirit were used, and (2) heating the air to a comparatively high temperature and spraying the oil into it, this also reducing the work output. The Fillet carburetter, introduced at the Paris Salon of 1901, and whose improved form is described below,

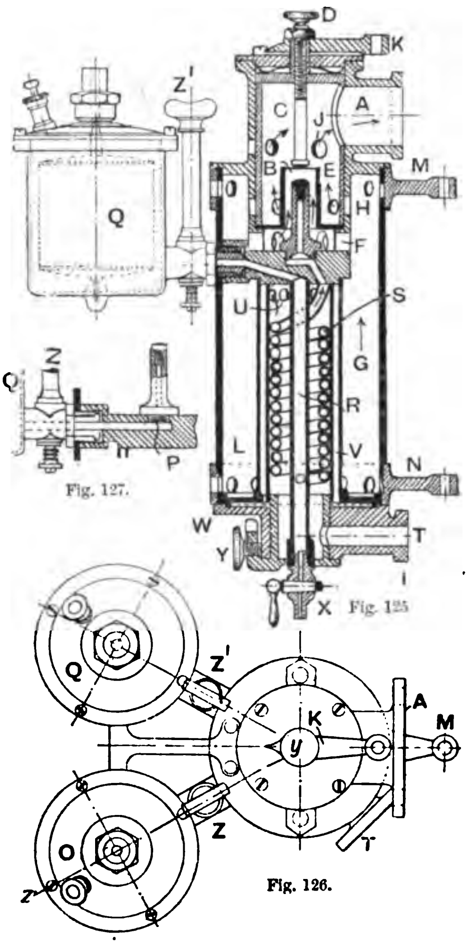


Fig. 127.

Fig. 125

Fig. 126.

Figs. 125 and 126.—Section and Plan of Fillet Carburetter.
Fig. 127.—Section of Spraying Nozzle.

accomplishes the above object by heating the oil itself until it answers for all practical purposes as if it were spirit. This method increases instead of diminishing the output of the motor. Petrol, alcohol, or ordinary paraffin oil can be used in the carburetter, but it is specially designed for use with the last named, so as to give greater convenience, safety, and economy than when the more volatile and expensive spirit is employed. Fig. 125 is a vertical section and Fig. 126 a plan of

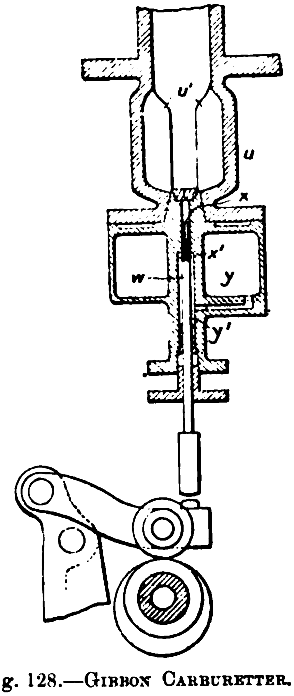


Fig. 128.—GIBBON CARBURETTER.

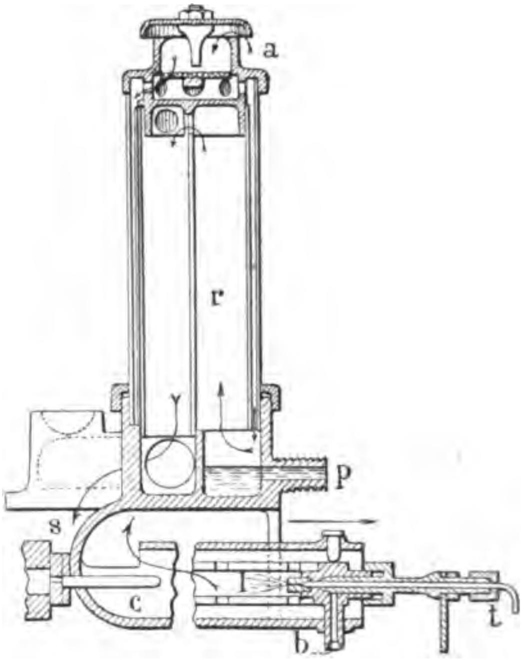


Fig. 129.—FAURE PETROLEUM CARBURETTER.

the device which actually is a float-feed spray carburetter having two float-feed chambers; in a prolongation below the spraying chamber is an exhaust-jacketted worm used only with the heavy oil. Referring to Figs. 125 to 127 (Fig. 127 being a section on *z y*, Fig. 126) A is the motor intake pipe, B is a nozzle which throws the liquid against the spherical end of rod C, whose position is controlled by the milled head, D, this regulating the degree of pulverisation accordingly. Between nozzle B and sleeve E air is admitted through holes F communicating with jacket G. The additional air required comes through two holes, H and J. A sleeve connected with handle K has corresponding holes so arranged that more or less cold air is admitted directly through J, and more or less hot air through H, according to the position of handle K. The jacket G has a row of holes at the top and another row L at the bottom, and either set can be opened or closed to a greater or less extent by moving outside perforated rings regulated by handles M and N; the air supply is warmed by opening the lower set of holes and cooled by opening the top set. Intermediate positions of the handles give intermediate temperatures. Float chamber O communicates directly with space P below nozzle B, whilst float chamber Q communicates with vertical pipe R, down which flows the heavy oil, ascending through the exhaust-heated coil S to the base of the nozzle. Exhaust gases enter by pipe T, pass up outside the worm S out through holes U and down through jacket V, finally escaping to the atmosphere by an aperture (not illustrated) in the casting W. The cock X drains the oil from the coil. The bottom casting holds the sleeves forming the jacket V in position, and by unscrewing the set screw Y both sleeves and casting can be removed and the worm inspected and cleaned. Cocks Z and Z^1 control communication between the carburetting chamber and the float chambers O and Q. For work, the float-feed chamber O is connected to the petrol spirit tank and the other chamber Q to the paraffin oil tank. Cock Z^1 is opened so as to prime the coil, and the oil rises in the nozzle B, filling up the pipe R and the worm S. Cock Z^1 then is closed and drain cock X opened so as to lower the paraffin oil below the nozzle. The petrol spirit cock Z then is opened, and the motor started in the ordinary way. When the motor has run on spirit for a short time and it is desired to change over to heavy oil, the cock Z is opened, and the heavy oil descends through pipe R and rises through worm S, mingling at the same time with the petrol. The petrol spirit cock Z then may be turned off, and the motor run on the oil alone; although, if desired, the two fuels can be used together, the two float-feed chambers Q and O working conjointly.

The Gibbon carburetter for petroleum (Fig. 128) has a valveless pump, $x\,w$, which injects petroleum through $x^1\,y^1$ from tank y into the atomiser above. This atomiser is a bell-mouthed tube u, with wings u^1 partly entering the combustion chamber, of which it forms the igniter. A casing fits lightly around the latter and prevents its being cooled by contact with the cool air. At starting, it is heated by an exterior lamp, and afterwards the charge ignites spontaneously after each compression.

In the Faure carburetter (shown by Fig. 129) the petroleum is brought by the pipe *p*, and the air by the cap *a*. This air follows the path marked in the figure by arrows, flowing through the compartments divided by wire gauze, and leaves by *s* on its way to the motor. The lamp *l*, for heating the tube *c*, which ignites the cylinder charge, also heats the petroleum contained in the vessel *r*. This lamp is arranged in the same manner as the burners of a petroleum furnace, and carries a small unstopping needle *t*. At *b* is seen the valve which admits the air necessary to complete the mixture.

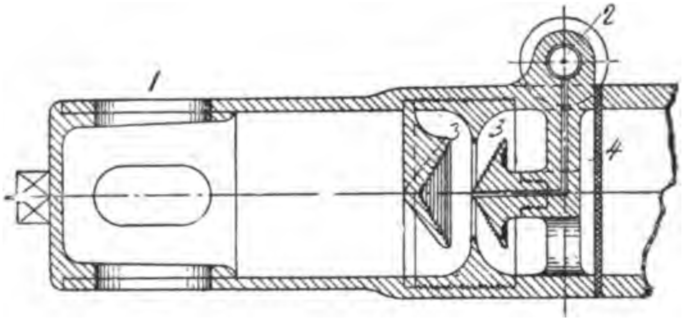
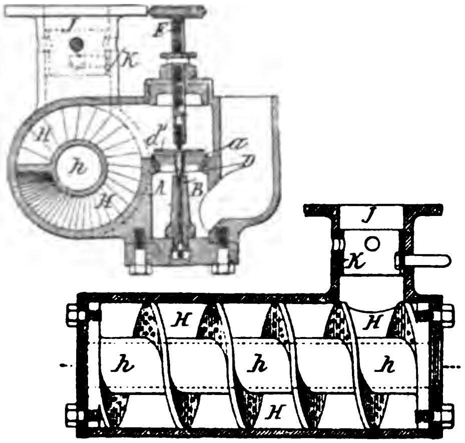


Fig. 130.—Dawson Carburetter.

The Dawson carburetter is shown in section by Fig. 130; it has a tubular body and at one end is a revolving cap containing air holes corresponding to the air holes 1 in the body; this cap adjusts the amount of air which enters. The baffle-block 3 causes the air to pass over the surface of a cone, and to go through a restricted passage formed by it, and also it provides an internal and stepped conical chamber into which the oil is delivered. An engine-operated pump feeds to the needle-valve 2 oil which afterwards passes through the small channel illustrated, and issues from the centre of a second ridged cone, which serves as a further baffle to the passage of the incoming air. The carburetted mixture thus formed is drawn through the wire gauze 4 to the motor cylinder.

The Martha carburetter is suitable for heavy oil and alcohol, and its improved form is shown by Figs. 131 and 132. Of two types, the larger is here described. The mixing chamber A contains a needle-valve D, normally closing the jet orifice B; the valve is adjusted by screw E, and spirit is supplied by a float-feed device. The valve needle has a flat plate *d'*, which is lifted by the incoming air and assists in the formation of the mixture. The sleeve *a* forms steps in the mixing chamber. The mixture passes into the spiral chamber H around the central exhaust pipe *h* to J, which communicates with the motor. The spiral plate forming the chamber H is perforated as shown, and assists by warming the mixture and making it more intimate; in the earlier form this plate was not perforated. The additional air supplied to pipe J is regulated by a perforated ring K Another type for cycle use is vertical, but it is on the same principle, the spiral chamber being retained, although the float-feed is suppressed, and the spiral plate is not perforated.



Figs. 131 and 132.—Martha Carburetter.

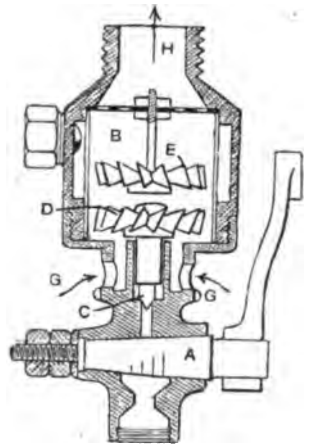


Fig. 133.—De Retz Caruretter.

The De Retz carburetter for alcohol adopts one of the features found in the Bouvier-Dreux device, p. 131. In one type (the B model shown in section by Fig. 133) the tap A controls the passage of the liquid to needle-valve C; the rather large spindle of the valve carries the fan D, which is lifted by the incoming air, and, revolving in one direction, causes the upper fan E to revolve in the other direction. The mixing chamber B is exhaust-jacketed. The extent of the valve lift is adjusted by altering the vertical position of the upper fan E. The air enters through holes G, and the mixture passes to the motor through H. The only regulation is that described above, and there is no float-feed or similar device.

The essential parts of the Gillet-Forest carburetter for use with either petrol spirit or alcohol are shown in Fig. 134, which illustrates a section taken through the spraying nozzle and motor supply pipe, this section cutting off the float-feed chamber and petrol arrival pipe, etc., which are of the usual kind. It is in the means of regulating the temperature of the air supply that this device is interesting. The petrol is brought to pipe A and ejected from nozzle B, below this being the cup C to catch any spirit not pulverised. The stepped spraying cone D is regulated by spring E, and by the screw with milled head F, the latter being kept in position by spring catch G. Hot water from the motor jacket circulates in H. The special device is the three-way cock J. Hot air from near the motor exhaust comes through the pipe K, cold air being admitted at the side of the cock. When the handle of the cock is down, hot air alone is supplied; when horizontal in front, only cold air; when vertical above, a mixture of hot and cold; and when horizontal at the back, the air supply is cut off entirely. This gives great facility of regulation, and should conduce to economy and efficiency. The charge passes to the motor through pipe L, the additional cold air required coming in quantity automatically regulated through valve M.

The Roubeau carburetter is designed for alcohol, and is shown in section by Fig. 135. The alcohol enters at the adjustable tap A to jet B, in which are several 0·25 mm. (·01 in.) orifices. Controlling the feed inside the jet tube is a valve C, whose spindle carries above the jet the inverted cone D. Normally, the spring E holds the valve C on its seat, the cone then nearly closing the passage of the air which enters through the holes F at the bottom; the size of these holes is rendered adjustable by a perforated disc G. The mixing chamber H is tapered lightly, and its upper portion J is corrugated to assist the mixing action. As the motor suction draws air through the carburetter it lifts the cone and simultaneously allows the alcohol to flow through the jet; then the mixture is formed under the cone and during its passage over the corrugated surface, and it then passes to the motor through K. The richness of the charge is regulated by the tap at the bottom.

A petroleum carburetter, known as the Moorwood-Bennet, recently was in successful use at the University College, Sheffield, and whilst, as far as is known, this is not applied in general to automobile purposes, its construction is such as to make its description here interesting. One of the principles of its action is the heating of the oil instead of the air, the latter being caused to percolate through the oil. The following particulars and the illustration, Fig. 136, are taken from the *Engineer*. The carburetter is a closed cylindrical vessel whose lower part A (Fig. 136) has two openings B and C, one communicating with the engine exhaust and the other with the atmosphere. The upper part D communicates with the motor cylinder through the pipe E. Of two concentric cylinders inside A, the larger F is connected by a pipe to the reservoir G. The cover at the top of A is perforated as shown, so that the two parts A and D are in communication. Air reaches the innermost cylinder H by means of the perforations J shown at the top, and the lower end of H

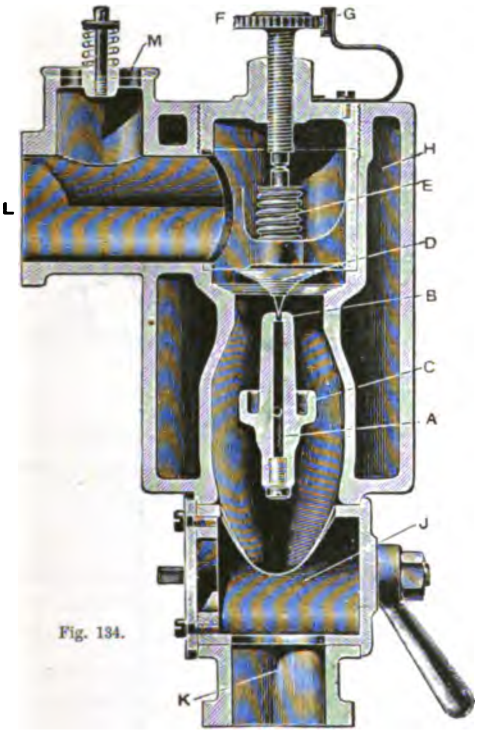


Fig. 134.

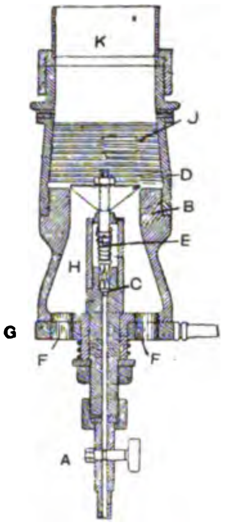


Fig. 135.

Fig 134.—Gillet-Forest Carburetter.

Fig. 135.—Roubeau Carburetter.

goes nearly to the bottom of cylinder F, and is shown enlarged by the side illustration. Inside the disc or flange K slides a tube with holes M and a flange L at the bottom; and the spindle N, having a screw and a hand wheel at its top, regulates the distance which the tube slides into H. The perforations are closed if the

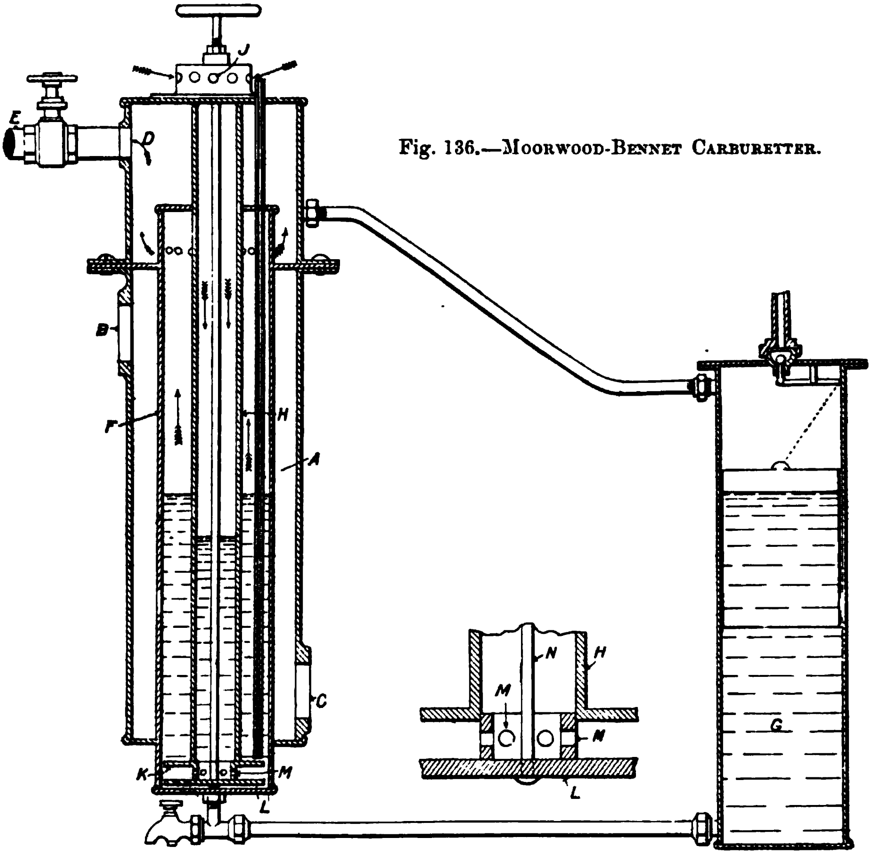


Fig. 136.—Moorwood-Bennet Carburetter.

tube is drawn up, or they can be open as illustrated, or be uncovered to any intermediate extent. With regard to the action of the apparatus, the suction of the motor piston causes air to enter at J, to pass through the oil in H, through the openings M, up through the oil in F, out at the holes in the top into D, and thence through pipe E to the motor cylinder. The exhaust gases in the jacket A warm the oil and facilitate working. Originally an oil-separator, to catch all oil still in liquid form, was interposed between the carburetter and the motor, but the use of this was discontinued, or at any rate it is not an essential. Russoline and other petroleums are used, and practically all the by-products in the oil are prevented from entering the cylinder, and it is easy to draw off the deposit or residue from the carburetter whilst the motor remains clean, neither cylinder nor valves being clogged.

In some motors carburetting is not accomplished by any special separate appliance. The Koch (p. 274) motor is of this kind. During suction, in the discarded Kane-Pennington motor, the petrol spirit falls on a metal wire gauze of a spiral shape, placed in the upper part of the cylinder, and forming part of an electric circuit whose current ignited the explosive mixture. This slight rise of temperature sufficed, it appeared, to completely vaporise the petrol spirit.

The special vaporiser, it is hardly a carburetter, employed on the Roots and Venables petroleum cars is described in connection with the motor (*see* p. 273), of which it forms a part.

Carburation of the air before or after it reaches the motor cylinder was dealt with in the paper read by Captain Longridge, who evidently favours motors working on the Diesel principle—that is, those in which the pure air is admitted into the motor cylinder, compressed, the sprayed fuel introduced and ignited automatically. This method avoids all possibility of premature explosion, and allows of higher compression; with equal cylinder dimensions, it also supplies a denser charge. On the other hand, it is urged that the charge will be imperfectly mixed, and give imperfect and irregular combustion. It is doubtful whether for petrol spirit there is anything in this objection, or whether, if there is, it is not more than discounted by the advantage gained. A number of petrol motors run successfully by merely injecting the petrol into the cylinder and letting the air and heat do the rest. In the American Weber petrol motor, for instance, no vaporiser is used, and the petrol does not come into contact with air until it reaches the combustion chamber. The American Otto petrol motor does not use a carburetter; the fuel is pumped from an air-tight tank to a valve acted on by the governor. This admits a given quantity to the cylinder, when it is immediately pulverised by the incoming air and rendered explosive. No air reaches the petrol on its passage from the tank to the cylinder. In the German Lützky petrol motor of the Maschinen Gesellschaft, Nuremberg, the spirit is conveyed to the cylinder in a liquid state and vaporised with the stroke as needed. In fact, in very many German petrol motors care is taken to exclude the air until the oil reaches the cylinder, even where a separate vaporiser is used. Thus, in the Dopp oil motor (Berlin) each charge of oil is converted separately into vapour without air, and highly superheated before it is admitted, in finely divided currents, to the combustion space, where it is mixed with air. Dopp claims that this method ensures regularity and completeness of combustion, low oil consumption, and quiet regular working without vibration. In the Russian Kablitz motor car, also, naphtha is injected into a red-hot vaporiser open to the cylinder, and immediately vaporised by the compressed air. Captain Longridge concludes that, for petrol spirit at least, carburation at the end of the stroke, admitting the use of higher compressions is probably as good as, if not more economical than, the more ordinary method; but it probably requires high compression.

A few general remarks on carburetters may here be given advantageously. The atomising apparatus is better than the surface types, as has been shown. The direction and strength of wind and the outside temperature may often cause, during a journey, some variation in the physical condition and quantity of air admitted into the carburetter, and thus necessitate at least an alteration in the working section of the air inlets. However, with a good atomising carburetter, this regulation or alteration is easy enough, and the apparatus is not disturbed by the jolting of the vehicle. Consequently, most automobiles are provided with an atomising carburetter. Motor cycles, on the contrary, were until recently obliged to dispense with them, because, in this case, the suction of the motor is not always powerful enough, however little may be the power needed, to bring the atomising carburetter into work, open a valve, and convey the petrol spirit into the apparatus. This power is not always obtainable, because in motor cycles variation of the amount of the charge taken in by the cylinder is the only means generally of obtaining different rates of speed, and when this intake decreases below a certain point, suction simultaneously gets feeble. But in spite of all this, spray carburetters give satisfaction on the Werner, Minerva, Davison and other motor bicycles. Ignition advance (*see* p. 187) is not adopted to vary the speed but rather to follow already accomplished variations by producing ignition at the precise moment when it is most advantageous for the good combustion of the explosive mixture.

To prevent flames from entering the carburetter and causing fire, a risk particularly to be dreaded with a surface carburetter, in which there is always a considerable accumulation of petrol spirit, a wire gauze partition must be placed in the pipe, as much as possible at a point where the diameter is enlarged, so that the working section will remain sufficient. This communication of flames may be caused by the inlet or exhaust valves not shutting at the proper time.

Finally, as an example of combined mixing and inlet valve, the Carlton device may be mentioned. It is shown in section by Fig. 137, and is designed to replace the ordinary induction valve. A cylindrical body, A, carries valve B, whose spindle C works in a guide supported by perforated plates D. The valve normally is kept closed by spring E, and a hollow in the upper part of the valve rod carries a small needle, F, pressed upward by a small compression spring. The needle is prevented from rising above a certain point by the pin G in slot H. The cover J has air inlet holes, and the plate ring K is also perforated and acts as a regulator, being locked by nut L. The petrol nozzle M screws into the cover, and the needle F normally prevents the flow of spirit into the valve chamber. There is a gauze plug, as shown, in the nozzle M. At each suction stroke of the motor piston the valve B is drawn downwards and the withdrawal of needle F allows spirit to pass into chamber A, whence it is carried by the entering air through the valve B into the motor cylinder in the form of explosive mixture. The flow of spirit is regulated by screwing in or out the nozzle M, and so varying the distance between the nozzle and the needle. N is the union.

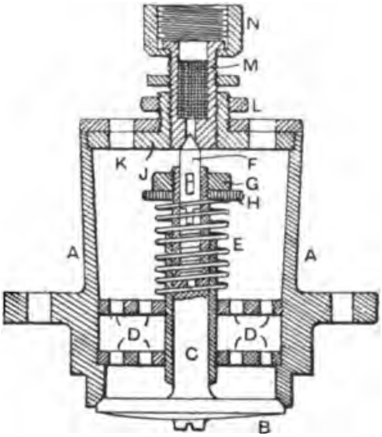


Fig. 137.—Carlton Combined Mixing and Inlet Valve.

CHAPTER VI.

PETROL MOTORS.

Petrol motors employed on automobiles belong, it may be said, to the compression and combustion type, and the Beau de Rochas four-stroke-cycle of operations, known in Great Britain as the Otto cycle, is employed almost exclusively. This cycle comprises the four following piston strokes:—

First forward stroke of piston = suction stroke, carburetted mixture is admitted.
First return stroke of piston = compression stroke, charge is compressed.
Second forward stroke of piston = working stroke, charge is ignited.
Second return stroke of piston = scavengering stroke, gases of combustion are expelled.

Thus there is only one working stroke in every four, two forward and two return, and there are two revolutions of the crank shaft for every four strokes; consequently a heavy fly-wheel is required, and the fewer the motor cylinders the heavier must be the wheel, though, as often is the case, if the pistons are not coupled so as to act on opposite cranks, multiplicity of cylinders does not usually allow of the size of the fly-wheel being decreased. Theoretically the two-stroke-cycle motor, giving one working stroke per revolution of the crank shaft, would be more rational, but there is great difficulty in realising it. The Benz type, which was invented to work with a two-stroke-cycle, now is made only on the four-stroke-cycle. It may also be remarked that existing four-stroke-cycle motors perform 600 or 700 revolutions (sometimes 1,000 and 3,000) per minute, thus giving a regularity far removed from the results given by Daimler's 150 or 200 initial revolutions. Moreover, motors of the four-stroke-cycle consume less fuel than motors of the two-stroke-cycle. However, the two-stroke-cycle motor is practicable, being employed by Loyal, Conrad, and Dufour; and there is even a six-stroke-cycle motor, this being made by François Goret, the fifth and sixth piston strokes being intended to cause a flow of pure air through the cylinders, so as to have the carburetted mixture constant and uniform and capable of ready ignition. This flow of air has the advantage also of cooling the motor cylinder. Before leaving alternating motors, mention must be made of the James F. Duryea motor, constructed on a new principle, combustion taking place in a special tank acting the part of the boiler in steam motors, and supplying the cylinder with gases under pressure. The Diesel motor, also, will have to be considered, although this, as far as is known, has not yet been applied to automobiles, but it perhaps will soon give them considerably greater efficiency than they now possess. Finally, brief mention will be made of the efforts put forth, in spite of difficulties, by some constructors with regard to applying the rotary principle to petrol motors. Four of these progressive constructors are Vernet, Batley, Dodement, and André Beetz.

In most of the four-stroke cycle motors the carburetted mixture is admitted into the cylinder by automatic valves retained on their seats by the pressure of a spiral spring and opening under the sucking action of the piston. The escape of the products of the explosion is assured by a valve worked by levers and a cam fixed on a shaft connected with the motor shaft by a system of toothed gears which make the cam shaft rotate once whilst the motor shaft rotates twice; thus, the exhaust valve opens once during every two revolutions of the motor shaft. But the advantages of mechanical operation for both valves have become more apparent lately, and there has been a revival in their use. Many of the most modern motors described in the next chapter are so fitted, the Mercedes motor being one of the number. Numerous devices for valve actuation by magnetic attraction, compressed air, exhaust pressure, etc., have been patented, and Captain Longridge offers several reasons why with high-speed motors mechanically operated valves are preferable to automatic spring induction valves. Owing partly to clearance and partly to back pressure from the silencer, the cylinder at the end of the exhaust stroke is filled with burnt gases above atmospheric pressure. When the piston, therefore, begins the induction stroke, these have to expand before air can be drawn in by suction, hence the automatic inlet valve is sluggish in opening. This is just the reverse of what should be, for the valve may even have a "lead" to assist the scavenging of the combustion chamber (this point is dealt with below). Again, the automatic valve closes at the end of the suction stroke, whereas it might be better to keep the inlet valve open a trifle after the piston had begun the compression stroke, that is, before the slight vacuum in the cylinder has been converted by the piston into compression above atmosphere. By so doing, the momentum of the air in the inlet pipe tends to add to the volume of the charge. (For automatic induction valves, very weak springs appear the best.) It may be noticed that where governing by volume throttling is used, if the spring of the exhaust valve weakens, the increased suction of the piston on the intake stroke may cause exhaust gases to be drawn back through the valve into the cylinder, with the risk of a miss or a slow firing through the presence of exhaust gas round the sparking plug, or of premature ignition, if the gas is hot.

Whatever may be the mechanical means employed to assure distribution, the various phases should be perfectly regulated, particularly as regards exhaust. Theoretically, exhaust should begin at the end of the second forward stroke, that is, the working stroke of the piston, but practically it begins a little before, so that there is a little lead in the exhaust. This lead, far from decreasing the power gathered by the piston, in allowing a slight amount of the pressure of the gases to be lost, augments the piston force by preventing an otherwise considerable counter-pressure from arresting the impetus of the piston during its return stroke. In fact, just as ignition advance, as explained on p. 187, is arranged to give the combustion time to take place perfectly, so the advance in the exhaust allows the exhaust to be quite complete before the following suction stroke begins. Lead or advance in exhaust is even more necessary than advance in ignition, because the evacuation, which occurs with a constantly decreasing pressure, is certainly less rapid than the combustion. Needless to say the advantage in question increases as the motor revolves more rapidly. With only 400 or 500 revolutions per minute there is hardly any advantage, practically none, but it begins after this rate. It must be remembered that 2,500 revolutions per minute (often attained by small motors like the de Dion-Bouton) correspond to 5,000 strokes to and fro per minute, that is about 84 strokes with 21 combustions and 21 exhausts per second.

The more usual motor speeds are given in the following table, which is due to G. Knap.

MAXIMUM MOTOR SPEED; GEÖRGIA KNAP.

Bore of Cylinder.		Piston Stroke.		Revolutions per Minute.
cm.	in.	cm.	in.	
6·2	2·44	7	2·75	1,400
6·6	2·59	7·3	2·87	1,800
7·2	2·83	8	3·15	1,700
8	3·15	12	4·74	900
—	—	11	4·33	1,000
8·5	3·35	15	5·9	750
—	—	12·5	4·93	800
9	3·54	15·5	6·1	700
—	—	13	5·12	750

As for shutting the exhaust valves, this should be done as indicated by theory at the precise time when the second back stroke of the piston ceases. Did it take place earlier the residual gases would prevent the piston from reaching the end of its throw and the new gases from filling the cylinder during the following suction stroke; and were it to take place later the burnt gases would be sucked in at the same time as the carburetted air, and there would be great difficulty in starting the motor to set it to work. In fact, during the first suction strokes pure air would enter by the exhaust valve at the same time as carburetted air entered by the inlet valve, and the mixture would be diluted with an excess of air and would not be combustible. The mixture would become combustible only by progressive enrichment after a considerable number of cylinderfuls, the exhaust valve allowing the entrance of a mixture successively more and more carburetted. The exhaust can be well regulated by suitably cutting the cam governing the valve, and often this regulation can be done only after long trials.

With regard to the material of valves, their seating and fitting, opinions differ, but the best practice is to have the spindle and head of different materials, one-piece valves being as a rule weak in the neck. The Wolseley inlet valve (Fig. 138) has a hard cast-iron head, A; this is made red hot, and into it is screwed very tightly the steel spindle B, which then is riveted over in the tapered part. The actual seat, C, of the valve is chilled to make it as hard as possible, and finally the pin D is fitted between the spindle and head. This is claimed to have given every satisfaction. Sometimes the heads of exhaust valves are made of rolled nickel in preference to steel, because steel is liable to a deposit of oxide which destroys the gastightness of the joint; again, iron and steel are attacked by the aldehyde and acetic acid produced by the imperfect combustion of alcohol. The nickel heads are brazed on a spindle of hard Bessemer steel, which sometimes is covered with nickel to prevent corrosion by the hot gases. The valve-seats may be of cast iron or cast steel, the latter being very suitable for nickel-covered steel spindles, and they should have a perfectly uniform thickness, so that expansion is the same in all directions, and the joints remain good. In the Wolseley exhaust valve (Fig. 139), scaling on the inner side is prevented by forming a baffle plate, A, in the casting between the cylinder and the valve B on the seating C.

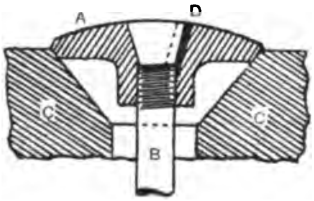


Fig. 138.—Wolseley Inlet Valve.

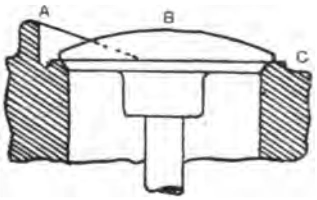


Fig. 139.—Wolseley Exhaust Valve.

For the heads of valves, Captain Longridge favours nickel-steel, and states that though cast-iron wears well, it seems hardly strong enough for small valves. Burning, irregular wear, and breakage of valves usually have been ascribed to weakness in the neck, unsuitable material, faulty methods of lift, throttling of the exhaust by insufficient area of the valve, exhaust pipe, or silencer. Any deficiency here may lead to broken valves. With a choked exhaust, according to Captain Longridge, the pressure left in the cylinder combined with the spring may produce hammering of the valve on its seat, and in time brittleness and fracture. There is, however, another cause of a very different nature. A defect frequently found in horizontal plunger pumps is the placing of the valve seat on a level with the waterway; then the discharge is greater on one side than on the other, and the water, diverted into a new direction by the valve, exerts a tilting force on it, and presses it towards the waterway. The results are irregular wear, sticking, and hammering of the valve on its seat. Now the usual disposition in the vertical motor is similar, with the same unequal discharge, similar tilting action, and the tendency to force the valve from its true position. The pump valve, spindle, seat, and guides are in the best condition to resist wear, but the motor valve beat is extremely rapid, the gas-flow swift, the pressure high, and all surfaces so highly heated as to be in the worst condition to withstand attrition and deformation. The remedy in both cases is the same. The motor valve seats should be kept below the gas passage, as in Fig. 140, so that the rush of gas acquires a straight downward course before reaching the valve. All tilting action is thus eliminated. Naturally, the usual precaution of fully equal area in the annular space round the valve to that of the valve outlet must be preserved. Captain Longridge observes that by far the better practice would be to avoid port passages and place the inlet and outlet valves on the head of the combustion chamber. With the heavier oils this position has the additional advantage of direct charge admission without possible condensation by contact with the port and cylinder walls. Of course, it slightly increases the height of the motor. Examples of valves so placed are the Buchet motors, the 3-cylinder 20 horse-power Maudslay motor, and the Belsize motor. The D'Equevilly valve (Fig. 141) is set on the top of the compression space, and one port serves for exhaust E and inlet D. The exhaust valve is sufficiently large to form a seating for the inlet valve, which opens into the induction passage, and the cold charge entering keeps the exhaust valve cool. F, the cap of the exhaust valve spindle, is actuated by a two-to-one shaft and rod, not shown. J is the exhaust valve spring, H a weaker spring for the inlet. The shock of the exhaust

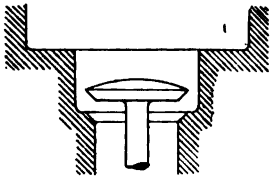


Fig. 140.—VALVE WITH LOW SEAT.

spring valve closing bounces the inlet valve at the same moment. The inlet valve stem is fluted, as shown in section (X) across A B, forming channels for the charge to the head of the valve.

The following table shows the diameters of exhaust valves according to French practice:—

EXHAUST VALVE DIAMETERS: FRENCH PRACTICE.

Bore of Motor Cylinder.	Diameter of Exhaust Valve (varies with Piston Stroke).
6·5 cm. to 7 cm. (2·56 in. to 2·75 in.)	18 mm. to 25 mm. (·7 in. to ·98 in.)
7·5 cm. to 8·5 cm. (2·95 in. to 3·34 in.)	25 mm. to 32 mm. (·98 in. to 1·25 in.)
8·5 cm. to 9·5 cm. (3·34 in. to 3·74 in.)	30 mm. to 38 mm. (1·18 in. to 1·49 in.)

The second table is due to Captain Longridge, who gives the valve lift as 5 mm. to 6 mm. (·196 in. to ·236 in.) for a cylinder bore of 6 cm. to 7 cm. (2·36 in. to 2·75 in.), and as 8 mm. to 9 mm. (·315 in. to ·354 in.) for a bore of 7 cm. to 9 cm. (2·75 in. to 3·54 in.), whilst the ports may be 5 mm. (·196 in.) larger than the valve, and the pipes the same amount larger than the ports.

DIAMETERS OF INLET VALVES AND PIPES: FRENCH PRACTICE.

Bore of Cylinder.		Piston Stroke.		Diameter of Inlet Valve.		Diameter of Inlet Pipe.	
cm.	in.	cm.	in.	mm.	in.	mm.	in.
6	2·36	7	2·75	15	·59	18 to 20	·7 to ·78
6·5	2·56	7·5	2·95	18	·7	20 to 22	·78 to ·86
7	2·75	8	3·15	19 to 20	·75 to ·78	22	·86
—	—	8·5	3·34	21 to 22	·82 to ·86	23	·9
7·5	2·95	9	3·54	22 to 23	·86 to ·9	24	·94
—	—	10	3·93	23	·9	25	·98
8·	3·15	12	4·74	24	·94	27	1·06
—	—	14	5·49	25	·98	28	1·1
8·5	3·34	14	5·5	26	1·02	29	1·14
—	—	15	5 9	27	1·06	30	1·18
9	3·54	15	5·9	28	1·1	32	1·25
—	—	16	6·29	30	1·18	35	1·37

In connection with valve areas, Captain Longridge states that the use of the sluggish-acting automatic inlet valve increases the difficulty of ensuring a full charge at high speeds; and in such cases, if 24·38 m. (80 ft.) per second for induction and 30·48 m. (100 ft.) per second for exhaust are to be at all approximated, the valve areas can scarcely be too ample. There is little doubt that in the aspiration method of carburation, the sharp blast supposed necessary to secure proper suction and mixing of the petrol has hitherto militated against the use of large-sized inlet pipe and valves. An instance of the tendency to enlarge valve areas is the Napier so-called pyramidal or annular valve (Fig. 142), which claims, with the same lift, to give 50 per cent. larger passage than the ordinary mushroom valve of the same diameter. A is a cylindrical valve seat; B and E are annular flat face rings, with connecting radial webs D. The ring E is on a sleeve C, forming a bearing for the valve spindle F. When the valve opens, the gas passes through the annular space between the seatings B and E, and also through the space P round the head I. The new Centaure motor (Panhard and Levassor) has

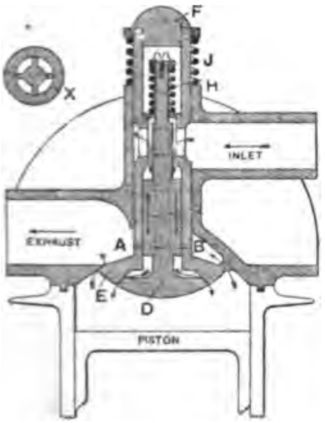


Fig. 141.—D'Equevilly Valve.

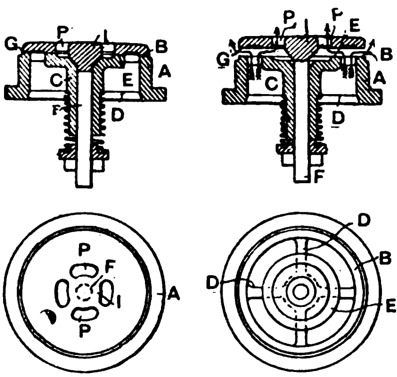


Fig. 142.—Napier Annular Valve.

a similar triple-induction valve. There is no difficulty in calculating the area of the induction valve, but with the exhaust valve the problem is less simple. In any case, the common practice of making inlet and exhaust valves of equal area cannot be right. Formulæ have been given, but appear to be incomplete because they do not state what are the resulting velocities of the gas flow, and they are defective because they apparently assume discharge at equal pressure in all cases.

The diameter of the exhaust pipes should be greater than that of the valves to avoid strangling the gases and to assure their expansion. In order to bring the lift of the valve to the normal standard which it is essential to retain, and which the play of the joints tends to destroy, the valve rods are furnished with adjusting screws. The springs which press the exhaust valves against their seats must be powerful enough to prevent the valves opening during suction and the burnt gases from re-entering the cylinder. To avoid their being softened under the action of heat, sometimes devices are adopted to insulate them from the motor or at least to remove them to a distance from its hot parts. Suction is easier to regulate than exhaust; the valve and inlet pipe for the carburetted gas should have a sufficient suction to enable the cylinder to be filled rapidly; in a cylinder with bore of from 60 mm. to 90 mm. (2·36 in. to 3·54 in.), and piston stroke of from 70 mm. to 160 mm. (2·75 in. to 6·28 in.), the diameter of the valves varies from 15 mm. to 30 mm. (0·58 in. to 1·18 in), and that of the pipe from 18 mm. to 35 mm. (0·7 in. to 1·37 in.). The springs should simply maintain the valves on their seats.

Accessibility of valves is well provided for in all the better classes of motors. In the Daimler, the removal of one nut enables the bridge to be removed and the valves inspected. Similar devices are now found on most cars.

There are various methods of regulating the power of the motor. One method is to make the amount of petrol spirit conveyed to the carburetter proportional to the power to be developed, as is done in the Peugeot carburetter (*see* p. 128), and as is done by aid of a needle-valve in the Goret carburetter; or to vary the amount admitted to the suction chamber, as in the case of the Brillié distributor (*see* p. 139). Another method is to vary the amount of carburetted mixture admitted into the cylinder, and this—"throttling"—has become standard. Sometimes the power is regulated by varying the proportion of air admitted into the carburetter to be enriched or, rather, by varying the supplemental proportion of pure air added to the mixture to make it explosive. However, in the latter case there is a risk of the impoverished mixture failing to explode, and to obviate this risk compression must be modified in inverse proportion to the richness of the mixture. This is the correct idea which Malézieux endeavoured to apply by varying the height of the compression chamber, the bottom of the cylinder being with this object constituted by a movable piston. In this appliance the piston forms the end of a screw which passes through a nut in the end of the cylinder, the screw being regulated by means of a hand-wheel. An improvement would be to control the device from the driver's seat. Side by side with these devices, which are sometimes combined in the same motor, a real governor can be adopted. In this case a centrifugal force apparatus is employed to act on a throttle valve in the induction pipe connection to the carburetter, or on the mechanism governing the exhaust valve, which then is prevented from opening or shutting. In the latter case, the gases from the previous explosion remain in the cylinder, or instead the cylinder remains open to the outside air; in both cases carburetted air is not sucked in, and the driving phase or working stroke of the cycle is suppressed. Mostly, however, the governor acts directly on the admission, so as to throttle the inlet pipe, or to prevent the inlet valve opening. As a rule, governors are not so often used when tube ignition is employed. With electric ignition, the possibility it affords of hastening the moment of ignition may be reckoned on, as will shortly be made clear (p. 187). Generally cars furnished with governors also have accelerators, an accelerator enabling the driver to put the governor out of action and let the motor race for some time, to the detriment of its efficiency but to the advantage of the speed.

With regard to volume throttling, Captain Longridge points out that incomplete filling of the cylinder reduces compression, and renders the conditions for efficient and economical explosion less favourable. Again, the induction of the charge below atmospheric pressure entails negative work, often 7 or 8 per cent. of the effective indicated power.

Ignition of the explosive mixture is provided by two methods, the electric spark and the incandescent tube; the latter system, however, is falling rapidly into disuse. Electric ignition consists in producing a very hot electric spark, as blue as possible, in the midst of the explosive mixture. Usually it is an induction spark, sometimes the rupture spark reinforced by the phenomenon of self-induction, which is employed. To obtain the first, recourse is had to a Ruhmkorff coil, in which the current furnished by a primary or secondary battery traverses the primary circuit or coil inductor, upon which there is a contact breaker. Interruption of this current, occasioned by the trembler, causes a current in the secondary or induced circuit, and if this induced circuit is broken there is a spark at the point of interruption. In order that the sparks may be emitted only at the requisite moment, normally the primary circuit is broken, and only at the moment when compression finishes is it closed by a cam on the shaft which operates the exhaust; this shaft, it will be remembered, performs only one revolution whilst the motor shaft performs two, and the circuit is closed once every two revolutions of the motor, during one phase only of the four. As soon as the current is closed the contact breaker acts, and a series of sparks breaks out from the sparking plug in the explosive mixture, which at once ignites. This is the most rational device, and was once employed for the Benz cars; it has the advantage of employing current only at the moment of explosion. In certain Benz cars, however, the primary current passes all the time, and the secondary current is established without passing through the sparking plug; then the cam delivers it there at the moment when the spark is to be produced. De Dion-Bouton, fearing that such devices might not always produce the spark at the exact moment for ignition, has modified them by removing the contact breaker from the coil, and making the motor itself break the circuit and so give the spark. The primary current, after passing through the thick wire of the coil, reaches the interrupter worked by the motor; at every two revolutions of the latter the circuit is made, and immediately broken, producing in the secondary circuit the rupture spark which ignites the mixture. The electric current runs from its source through the coil, the igniter and its plate, which are normally in contact, and then returns to the initial point: at the desired moment the contact is broken and the spark is emitted. In the three cases above noted, by altering the keying angle of the ignition cam on the shaft which gives it motion, the production of the spark can be hastened or retarded.

The electricity for energising the igniting device which produces the spark is obtained, according to circumstances, from a wet or dry primary battery, a secondary battery known as an accumulator, a magneto-electric machine, or a dynamo. Wet batteries cannot be employed unless they are sealed up. A somewhat common type of wet battery is that of Bassée and Michel, which uses an exciting fluid of chromic acid solution. The receptacle is a rectangular parallel pipe made of celluloid 3 mm. (0·12 in.) thick, shut by a flat watertight lid. The zinc element generally lasts three months, and the chromic acid solution one hundred hours of work; the E.M.F. is 2 volts. The Clarence battery, which is very similar to the preceding, is employed, to some extent, also. The receptacle of this is made of vulcanite, which, unlike celluloid, is not inflammable, and two chimneys in the lid allow the gases to escape, whilst at the same time preventing the liquid being spilled. A cell of the small type, only containing 900 g. (29 oz.) of the exciting liquid, can work 60 hours, the E.M.F. being 2·25 volts. This high voltage, and the faculty of working at a constant discharge of one and even two ampères, are valuable advantages of sealed wet batteries, but their capacity is small. Under the influence of endosmosis, which is produced through the porous partition separating the two liquids, these last mix somewhat rapidly, and then the battery is unfit for use. Recharging is neither cleanly nor convenient, whilst the gas chimneys may allow liquid to escape, and the receptacles may be broken, the acid spoiling everything it touches. Consequently, dry batteries are preferred to wet ones, since it has been noted that the spark need not be so hot as was thought, and that ignition may be caused by a current at a pressure of 4 to 5 volts, and of one-tenth ampère in strength, such as dry batteries can supply. The dry battery, strictly speaking, is a battery with fixed liquids. In the Bloc battery, which is a modified Leclanché battery, they saturate cofferdam—a substance extracted from the exterior fibres of the cocoanut. A single cell of this type has an E.M.F. of 1·6 volt, and a very low internal resistance, but its weight and want of durability are disadvantages. A lighter and more durable battery seems to be the "Étoile" of the Société le Carbone, which recalls very nearly that manufactured by the same company for the de Dion-Bouton tricycles. It is very like a Leclanché without the zinc rod, the glass vessel being replaced by a metal box. This box and a special agglomerate element contained in a canvas bag are placed inside the zinc electrode, which forms an outer box, and from which they are separated by a layer of sawdust saturated with exciting liquid. The cell is closed by a layer of insulating material, through which are two small lead tubes for discharge gases. The E.M.F. is about 1·6 volt, and the internal resistance is slight. The useful capacity of a cell of average size on a resistance of 10 ohms is about 60 ampère-hours per kg. (27·3 ampère-hours per lb.) of active material. This battery gives a very regular current for a long time, though, like all other batteries, it is expensive.

Accumulators are mostly preferred, as in these the elementary material can be employed again and again, and they have the advantage of not offering resistance to the passage of the current through the coil; but they also have inconveniences. They disengage acid fumes, and the fall of active matter may cause short circuits. Accumulators will be dealt with fully when those employed for traction are described (*see* Chapter VIII., p. 299).

A dynamo for ignition is employed on the Panhard and Levassor (Centaure), Thornycroft, Decauville, and Toledo motors, whilst magnetos are used on a great number of motors, including the Mercedes, Brush, Mors, Peugeot, Benz, G. Richard, and Lanchester. Duflos-Clairdent proposed a small magneto machine with alternating current, so as to dispense with the contact-breaker of the coil. Houpied succeeded in carrying out this idea by mounting on the magneto or dynamo shaft a cam driving an interrupter. Needless to say, magnetos and dynamos are driven by the motor, and as they only work with it, the electricity for starting the motor must be sought for in some other source; generally this other source is an accumulator, which, when necessary, is recharged by the dynamo. However, there are self-sufficient devices, such as that of Houpied, in which ignition is started simply by displacing the motor fly-wheel. Dynamos and magneto machines give a hotter spark than primary batteries and accumulators, and consequently are more capable of causing complete combustion of a big charge. Knap noted a gain of from 15 kgm. to 25 kgm. (108·5 to 181 ft.-lb.) when employing a Houpied apparatus instead of a simple accumulator for igniting the charge of a small power motor.

Two magneto ignition systems of note are the Eisemann and Bosch. The Eisemann ignition system is practically a coil ignition in which the battery is replaced by a magneto generator, and Fig. 143 shows it arranged for four cylinders: A is the field magnet of the magneto, and the armature B is mounted on a half-speed shaft connected by the spur-wheels C and D with a separate shaft parallel to it, and carrying on its far end the high-tension commutator E. The spur-wheel C is not rigid with the armature shaft, but is integral with a sleeve carrying the pulley F, the sleeve driving the amature shaft by means of a pin, G; a fork, H, connected with a bell crank lever, controls the movements of the sleeve. This part of the apparatus controls the moment of ignition. The ends of the armature winding are connected to the two connecting rings I and J, with which the spring connecting brushes K L make contact. The current passes through the conductor M from the brush K to the primary winding of the coil, and through the contact breaker N O back to the brush L. The contact breaker O is operated by the double cam Q, which, as the spur-wheel C is designed to run at twice the speed of D, breaks contact four times for every revolution of the cam shaft of the engine. A condenser, Z Z, is arranged across the contact breaker so as to increase the secondary spark in the usual way. The condenser is

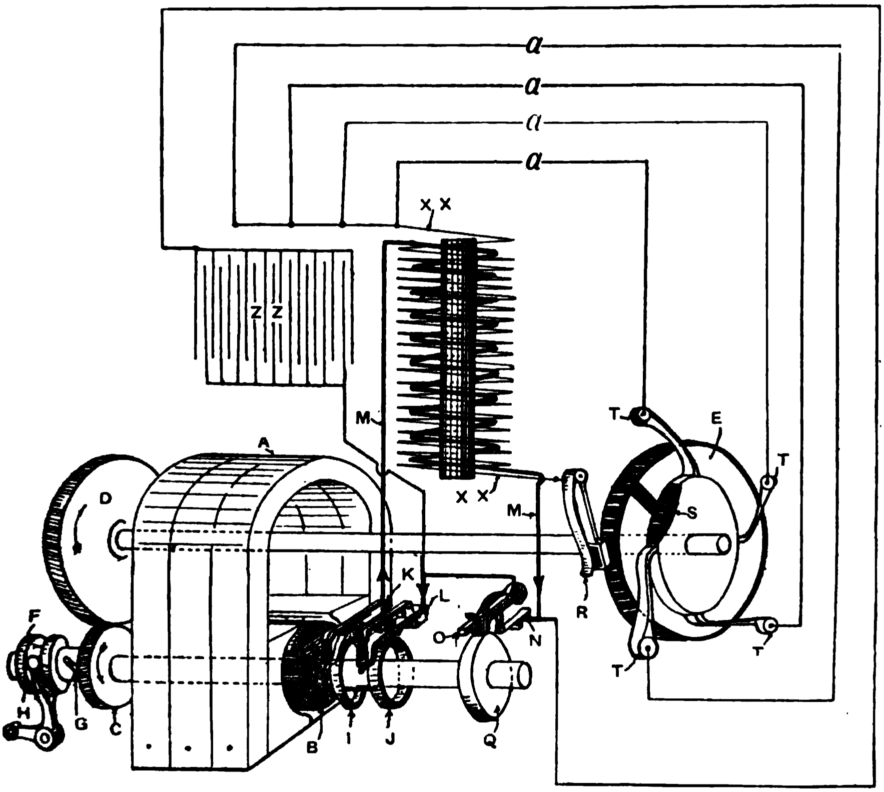


Fig. 143.—Eisemann Magneto Ignition System.

shown connected to N and O by thin lines, but in practice it is of importance that the wire to the condenser should be at least as thick as the primary winding of the induction coil. One end of the secondary coil X X is earthed and the other is connected to R, the brush of the revolving high-tension commutator or distributor. It will, of course, be understood that the current furnished by the armature B is an alternating one, but the cam Q is so arranged that the circuit is only broken when the current furnished by the armature is at its maximum in either direction. The high-tension commutator or distributor E receives current through the brush R, which runs no a metal ring forming the periphery of the wheel. This is in conducting connection with the segment S, which makes consecutive contact with each of the brushes T, leading to the sparking plugs *a*. The moment of sparking is determined by the breaking of the contact N O, the contact to any one of the brushes T having been made by the segment S slightly before that instant arrived, the connection being also maintained slightly after the spark has passed. This enables the spark to be advanced or retarded within the necessary limits by simply advancing or retarding the moment at which the contact breaker O is raised. The timing is effected by the fork H engaging with the guide pulley F : moving this to the right or left rocks the shaft carrying the cam Q, and the armature, relatively to the spur-wheel C, and by moving F to the right or left the moment of ignition may be varied as required. The advantages of this system are that it dispenses with a battery, and is as independent and reliable, therefore, as an ordinary low-tension magneto ; and it gets rid of all the difficulties connected with the make and break contacts mechanically operated inside the cylinder. There is, therefore, no difficulty in accurately synchronising the spark in all four cylinders, so that it may be said to comprise both the advantages of induction coil and ordinary magneto systems.

The Bosch high-tension ignition as applied to four cylinders is shown in Fig. 144, in which the permanent field magnet is shown upside down, for the purpose of enabling the different parts and connections to be better seen. The stationary armature A has two windings, B, of stout wire, and corresponding to the primary winding of an induction coil, and C, of fine wire, and corresponding to the secondary. For the sake of convenience it is shown nearly at right angles to its real position. One end of the winding B is earthed on to the shaft of the apparatus, and the secondary winding forms a continuation of the primary. The other end of the primary winding, B, is led to one side of the contact breaker D, and to one terminal of the condenser, the other terminal of the condenser and the moving arm of the contact breaker D being earthed. As in the low-tension forms of Bosch magneto, the changes of magnetism in the armature core which give

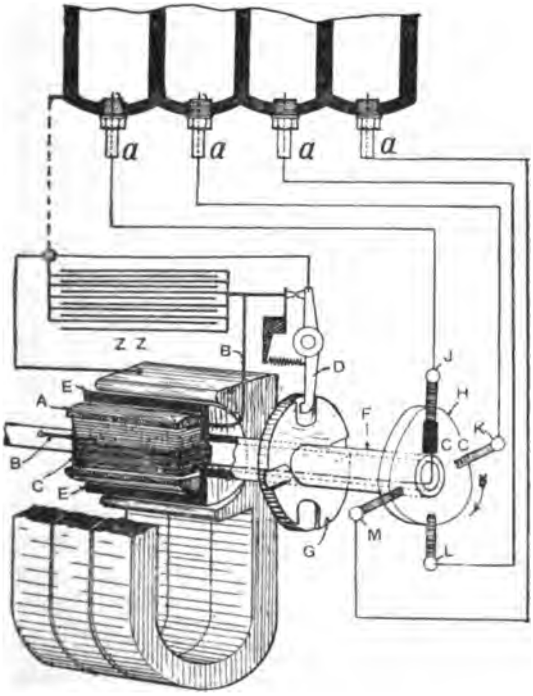


Fig. 144.—Bosch Magneto Ignition System.

rise to the current are produced by the rotation of a soft iron sleeve, E, which partially surrounds it, and is integral with the hollow shaft F, which also carries the notched disc G, and the high-tension distributing disc H. The action of the sleeve E is exactly the same as in the case of the low-tension magneto ; that is, if the sleeve E entirely encircled the armature, it would shield it completely from the action of the field magnet. It is, however, slotted, and when the slots come opposite the poles of the field magnet, the armature receives magnetism from the field magnet, and is deprived of it again as the slots pass round with great rapidity, and a powerful current is consequently induced in its windings. The contacts of the contact breaker D are normally held together by the action of the disc G, and during these periods the low-tension winding B is closed on itself, so that a powerful current flows through it at the moments when the magnetism of its core is being varied by the rotating sleeve E. When one of the notches in G, which are steep on the one side and bevelled on the other, come under the lower end of the contact lever arm D, the latter snaps back, owing to the action of its spring, separates the two contacts, and breaks the circuit of B. This produces a high-tension current in the secondary or fine wire winding C, just as in an ordinary induction coil, the condenser Z Z increasing the effect in the well-known way. The secondary winding, being connected to the primary as already described, and as it is earthed through it, successively connecting the central rods of the sparking plugs *a* to the opposite end of the secondary C, causes sparks to pass in the four cylinders at the right moments, the tension or voltage of the primary and secondary being added to one another. The distribution is effected by the commutator or distributor H. This consists of the rotating disc H, carrying the metal plate C C, which is in connection with the insulated end of the secondary winding C. As the disc revolves, this metal plate makes contact successively with the fixed brushes J, K, L, M, which it does in each case just before the notches in G cause D to break the primary circuit B. Sparks take place successively at the right moments accordingly in the four cylinders. The new Bosch ignition may claim practically the same advantages as the Eisemann, and is more compact, not having a separate induction coil; but the latter allows of advancing or retarding the moment of sparking, which, however, could be easily applied to the Bosch system by making the hollow shaft F displaceable relatively to the motor shaft in practically the same way. The description of the Eisemann and Bosch ignition systems are due to the *Automotor Journal.*

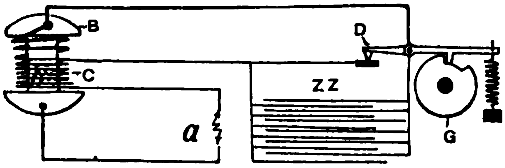


Fig. 145.—Bosch Ignition System for One-cylinder Motor.

Fig. 145 shows the new Bosch arrangement as applied to a single cylinder. All the parts are similarly arranged, except that the high-tension distributor is, of course, superfluous and is omitted. The new Bosch ignition is claimed to act in much the same way as a high-tension spark in combination with the electric arc, the high-tension spark being used to start the arc, which then follows across the path which the high-tension spark has opened up for it, with, of course, a vastly greater volume and heating power than that possessed by the spark which started it. It is hardly possible, however, that this can be the case, for the relatively great "thickness," that is to say, in reality amperage of low-tension sparks, as compared with high-tension, is due to the small self-induction in the circuits which produce them. In this case, however, the self-induction of the secondary is added to that of the primary, and the amperage or volume of the spark cannot be seriously greater than that which the high-tension winding would of itself allow to pass.

Fig. 146.

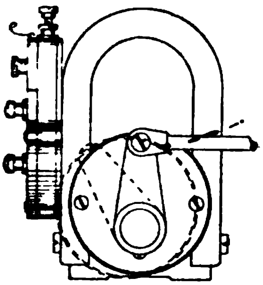
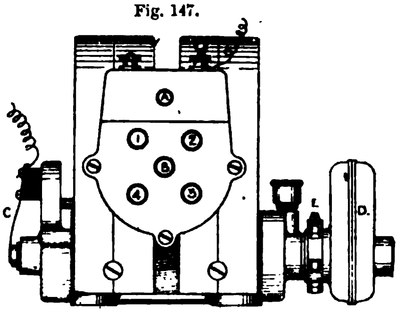


Fig. 147.



Figs. 146 and 147.—Dawson Ignition Magneto Machine.

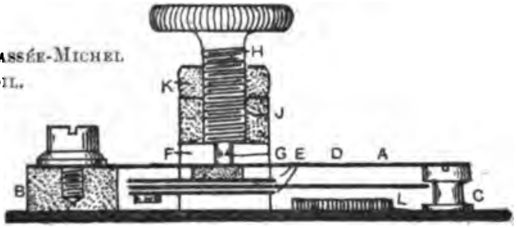
The Bergmann rotary magneto is said to have given satisfaction on the German Daimler car; it produces low-tension alternating currents, with which insulation is easy, while the only moving part is the rotary armature. The magneto, even at very low speeds, produces sparks sufficiently intense.

The Dawson ignition magneto machine (Figs. 146 and 147) is driven by a chain from the motor, the chain-wheel E driving the armature at a higher rate of speed through an epicyclic gear contained in the casing D; this casing also serves for varying the moment of ignition, which is effected by giving it a rotary movement about the shaft and by thus altering the relative angular positions of the chain wheel and the armature. The pulsating current is conducted from a collector C to the primary winding of an induction coil, of which the secondary or high-tension terminal is connected electrically to the terminal B. A distributing commutator, driven by a speed-reducing gear, is fitted on the machine, and this distributor alternately connects the high-tension conductor with each of the four terminals, 1, 2, 3, and 4, shown, from which separate wires lead to each of the sparking plugs in the four cylinders of the Dawson motor. The cover of the interrupter case is held in place by the nut A.

Coils employed for ignition must be very carefully constructed, on account of the vibrations they have to undergo, and for good service they must buzz vigorously. Often a coil can be made active again simply by rubbing with emery paper the end of the bundle of soft iron wires against which the clapper works. A large coil consumes less power than a small one, the heat of the spark being proportional to the length of the secondary wire; this detail should be noted, because coils which expend the least current are sought for in electric ignition. Normally, an ordinary Ruhmkorff coil gives 3 ampères, and Bassée and Michel manufacture coils which require only 1·5 ampère; those of Rossel require only five-tenths to seven-tenths ampère per hour. The Peugeot firm has employed the Rossel coils, energised by batteries made by the Société le Carbone, these batteries working for 800 to 1,000 hours. Coils without contact-breakers, it appears, are better when the motor performs more than 1,500 revolutions per minute, and they have always the advantage of reducing current consumption to a minimum, except, however, when at an untimely moment they allow current to pass without any warning; the buzz of the contact-breaker is valuable in this respect. The Aster motor employed a Rochefort coil.

The Bassée-Michel new high speed induction coil is shown in section by Fig. 148. The type for a one-cylinder motor has three terminals, the positive wire from the accumulator being attached to one marked P* (these letters refer to the actual apparatus and not to Fig. 148); the two others are B and C respectively, and to C the negative earth is coupled, whilst to B is attached the sparking plug high tension wire, the return high tension circuit being through the earthed wire to C. The magnetic trembler is a special feature: its blade A (Fig. 148) is screwed at one end to block B, its other end resting freely upon stop C. The blade carries a light block F, to which are fixed two spring plates E, supporting the iron magnetic plate D. The adjustable contact screw H (carried by bridge J), and the trembler A have good platinum contacts set squarely up to one another. When the coil is energised with current, the iron wire core L becomes magnetised and attracts the plate D, which being held between the unsupported spring plates, is free to swing on the light blocks F, this causing the trembler plate A to give in the centre where the platinum contacts are; these then are pulled apart squarely. When properly adjusted, the trembler is exceedingly sensitive, and the coil has been used on a Dion-Bouton motor running at 2,800 revolutions per minute, without a single miss-fire. When the contact screw has been set, it is locked in position by turning the hexagon nut K.

Fig. 148.—Bassée-Michel Coil.



The sparking cam, that is the cam that operates the sparking, is often a cylinder of insulating material, often compressed wood fibre; a metallic conductor connects the cam axis with its periphery, and when this conductor touches a metal contact, constantly pressed against the cylinder by a spring, the current circulates. The sparking plug is the element from the extremity of which the spark issues into the midst of the explosive mixture.

Essentially, the sparking plug is a wire occupying the centre of a porcelain cylinder held by a nut in a metal socket, itself forming a screw to fit into the cylinder head. The threads of this screw carry a small platinum hook, which is distant 1 mm. (0·04 in.) from the end of the wire. The wire from one side and the metal bulk of the motor from the other communicate with the secondary circuit of the coil, and as the porcelain cylinder insulates them one from the other, there is no short circuit between them, and the spark is emitted between the end of the wire and the platinum hook. The central wire is 1 mm. (0·04 in.)

less in diameter than the channel in which it is sealed with plaster-of-Paris. Frequently it is made of nickel, and then it has a bit of platinum brazed on at the sparking end. The non-oxidability of nickel is a valuable quality for preventing short circuits, which are particularly to be feared with the sooting of the plug. The term "sooting" implies the impregnation of the plug with soot, due to combustion of the explosive mixture when carburetting is bad. This soot penetrates the smallest cracks in the porcelain, more especially during compression of the mixture. To make sooting less frequent, a denser asbestòs porcelain has been proposed instead of ordinary porcelain. The construction of sparking plugs has been the object of important improvements. Bassée and Michel invented a plug that may be taken to pieces. In Fig. 149, which shows this plug, A is the socket, *a* the platinum point, C the steel washer to ensure tightening, B tightening nut, P porcelain pencil, T T central wire, R copper washer and asbestos, D brass cap, *mm* knurled nuts, *n* lock nut. The porcelain pencil, instead of being sealed in the socket, merely slips into it, gas-tightness being ensured by an asbestos packing pressed against the shoulder P by the nut B.

The Reclus sparking plug was designed with a view to prevent failure of sparking caused by variation in the spacing of the points (due particularly to their expansion) and rupture of the porcelain. To avoid the first, the central rod terminates with a massive bullet-shaped end instead of in a point, and this rod is never made incandescent, and always allows of the spark being made at any point on its circumference. During a journey this spark is emitted sufficiently forward in the cylinder to enter the midst of the new gases. To avoid breakage, the porcelain is not fixed in a screwed socket, but is fastened in its metal jacket by a special cement which prevents all leakage. Porcelain usually breaks, because one end is exposed to a great temperature whilst the other is cooled by the outer air, the expansion, in consequence, being unequal.

The Helical ignition plug, according to Baudry de Saunier, is so named merely because the wire of the secondary current is not fastened to it by a screw in the ordinary way, but first passes, twisted into a little ring, in the turns of a coil placed at the top (*see* the section Fig. 150). The advantage is that the porcelain is not broken when a clumsy attendant exerts too great a twist upon the nut in tightening up the wire. The usual defect of the central spindle getting too hot and its expansion causing the breakage of the porcelain is got over by this method of fastening the secondary wire. The central spindle is fixed to the porcelain in one place only (Fig. 150), and so is free to expand; and the common defect of one end of the porcelain being hot whilst the other is cold is done away with by making the porcelain in two pieces, separated by a non-conducting wad; difference of temperature then does not cause fracture.

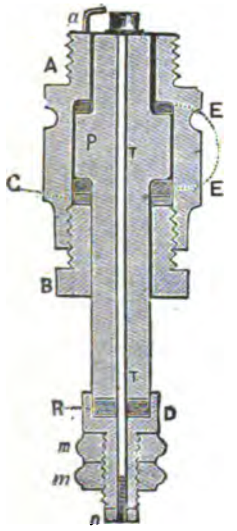


Fig. 149.—Bassée-Michel Ignition Plug.

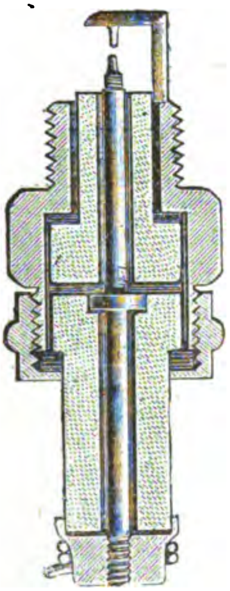


Fig. 150.—Helical Ignition Plug.

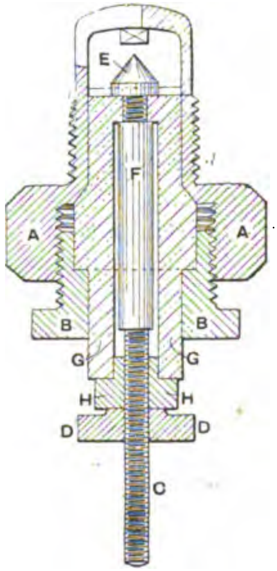


Fig. 151.—Steatite Ignition Plug.

In the Steatite ignition plug made by Frémy and Mare, soapstone or steatite replaces porcelain; it is easily machined in its natural state, is very hard and strong after baking, and has a high insulating value, whilst it does not appear to be so brittle as ordinary porcelain. The construction of the plug is shown by the section Fig. 151, in which A is a steel plug which screws into the cylinder wall and is fitted with a bridge piece across its inner end, the bridge carrying a contact piece at its centre. A block of steatite G fits inside the plug A, being held by screwed cap B, which forces the ground-in shoulder of the steatite to make a tight joint with the metal plug. The bore of the steatite is in two different diameters, and a brass rod C passes through it from the one end, where a steel top E is screwed to it, to the other end, where a brass cap H screws over it and holds it rigidly to the steatite. Inside the larger hole in the steatite a glass tube F surrounds the rod C. A milled nut D attaches a conducting wire to the insulated rod. The absence of packing in the joints between the metal and insulator is an advantage, and the plug may be recommended. In fitting it to small de Dion-Bouton motors, however, the bridge piece carrying the contact is liable to foul the induction and exhaust valves, unless when screwing the plug into the cylinder the joint is packed so that the bridge lies parallel with the valve heads; but perhaps the makers have already given attention to this slight defect.

The G. Richard plug, Fig. 152 is designed to overcome certain defects existing in the ordinary types; in these under the influence of the high temperature the cement fixing the rod to the porcelain deteriorates, or if, instead of cement, screws are used the difference in the expansions of the rod and the porcelain tube causes the joints to be altered in such a way that a current of gas or air sufficient to extinguish the spark may be produced around the rod. In the G. Richard plug, shown in section by Fig. 153, A is the porcelain tube enclosing the metal rod B, at whose end is a head C, separated from the end of the porcelain tube by a copper washer *a*; the little rod *b* is connected to the mass of the motor. At the other end of the porcelain is an asbestos washer *c*, over which is a copper washer *d*, pressed against by a spring R. According to usual practice, the rod B has its end threaded to receive the nut D, by means of which the rod B is held firmly in the porcelain tube; D receives the electric conductor *e*, which is held by the thumbscrew *f*. Owing to the spring R, compressed by nut D, the head C is pressed firmly against the tube A, and there also is a tight joint at the other end between *c*, *d*, and A. Thus a good joint is formed, which does not allow the passage of gas or air when the parts expand, the difference in expansion being met by the action of the spring.

The de Dion-Bouton new plug (Fig. 154) screws into the cylinder wall at A, and the inner extremity of the porcelain, B, has the form of an obus. Connection is made at C, the current passing back from the sparking point D through E and the mass of the motor wall. The porcelain is secured by the screw plug F.

The Peugeot ignition plug, shown in section by Fig. 155, has its construction based on the fact that carbon deposits do not tend to form inside small cavities in the combustion chamber; it will be noticed from Fig. 155 that the insulating surface inside the combustion chamber is considerable, and is placed in a deep cavity. The conducting wire *c c* passes through the porcelain *a a*, and is bent over to form the sparking point *d*. The porcelain has a collar *b b*, and is held inside the metallic portion of the plug by means of a screwed cap and insulating packing. The porcelain itself does not touch either of the outside metal parts at any point, and it projects some distance into the larger portion of the cavity. Between the porcelain and the metal plug in the smaller part of the cavity the distance is about 2 mm. by 20 mm. (0·078 in. by 0·78 in.).

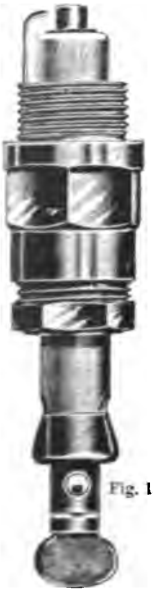


Fig. 152.

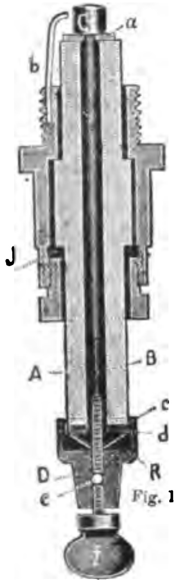


Fig. 153.

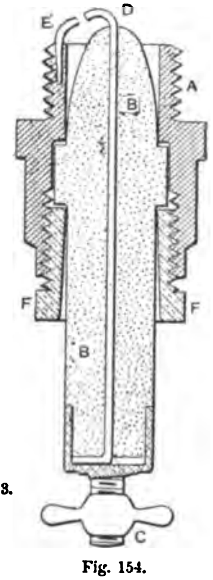


Fig. 154.

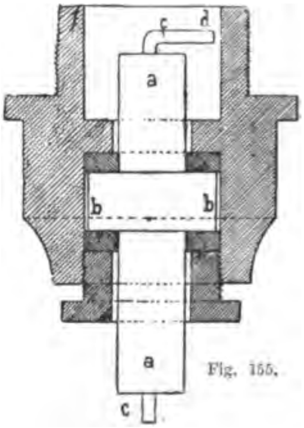


Fig. 155.

Fig. 152.—G. Richard Ignition Plug. Fig. 153.—Section of G. Richard Plug. Fig. 154.—De Dion-Bouton Plug Fig. 155.—Peugeot Plug.

The Automobilia attachment for preventing lubricating oil being thrown on the sparking plug is shown in section by Fig. 156. The attachment screws into the hole in the motor cylinder tapped to receive the sparking plug itself, and it is evident from Fig. 156, in which A is the cylinder head and B the sparking plug, that the chance of oil reaching the sparking points is remote.

The Panhard and Levassor ignition plug is of a special kind, and is the result of an accidental "discovery." When a high tension wire, instead of being attached to a plug conductor wire, is set at from 1 mm. to 2 mm. (·04 in. to ·08 in.) away from it. the spark jumps the interval between the platinum points within the motor cylinder, whether they are covered with oil or not, a second advantage being that it is easily seen whether the current is passing properly to the plug. The firm had protected the outer end of some plugs with an ebonite cap A (Fig. 157), fitted under which was a metal contact boss, B, from which current was conducted to the working end of the plug by a light copper spring. On removing the cap of one of the plugs the copper spring conductor was found to be absent between C and D, but in spite of this apparent faulty construction the firing was perfect; the coil used could give a spark 15 mm. (·59 in.) long, and the gap was only about 3 mm. (·118 in.), so this was not astonishing. But it was a surprise to find that, no matter how this particular plug was drowned in oil, it sparked as well as ever, though it failed to work when the connection was made quite complete, sparking through the oil again commencing when the connection was broken within the cap. The following is Baudry de Saunier's suggestion as to how this principle of constructing an oil-defying sparking plug may be easily applied: Screw an ebonite collar E

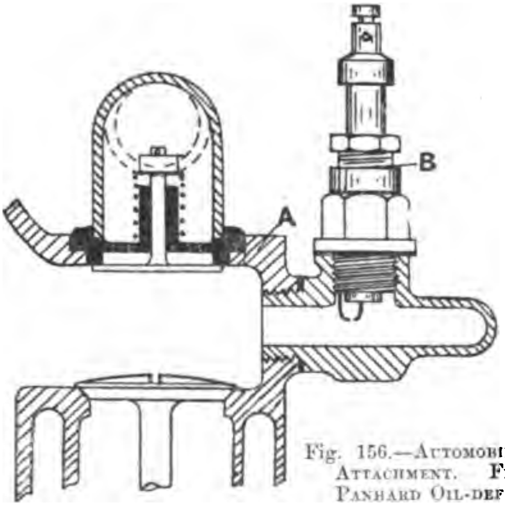


Fig. 156.

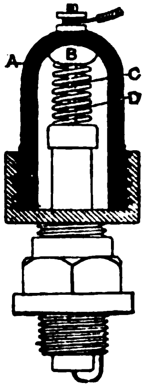


Fig. 157.

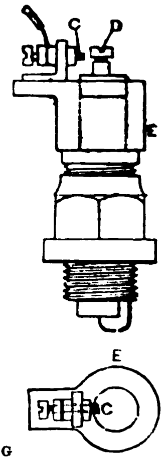


Fig. 158.

Fig. 156.—Automobilia Sparking Plug Attachment. Figs. 157 and 158.—Panhard Oil-defying Ignition Plug.

(Fig. 158) to an ordinary plug. The collar has an arm carrying a small copper angle piece drilled and tapped for the screw C, which with lock-nuts form an attachment for the secondary wire. The current then has to jump the distance of 1 mm. or 2 mm. (·04 in. or ·08 in.) between C and the head D, of the insulated pin in the plug. This principle is not new to electrical science, and now many plugs embodying it are on the market.

There is great difficulty in securing absolute synchronism of the operations forming the cycle in each cylinder in multi-cylinder petrol motors, and for this reason four-cylinder motors generally fail to give double the horse-power of two-cylinder motors of the same dimensions. Though care in design and accuracy of workmanship can ensure synchronism in many respects, there are certain contingencies which mechanical construction alone cannot guard against. Causes which are avoidable by careful manufacture are those arising from differences in the capacities of the combustion chambers from leaking pistons or valves, from variations in the length of the induction pipe between the carburetter and each cylinder, or from varying resistances to the escape of the exhaust gases from the cylinders. The chief source of trouble, however, has hitherto resulted from the electric ignition systems employed, and the difficulty which is experienced in tuning two or more coils, their tremblers, and their contact breakers, so as to bring them into unison with one another. The *Automotor Journal* has recently devoted much attention to this subject, and the following descriptions of three different systems in which the electric ignition apparatus is modified in such a way as to reduce this risk, are taken with the illustrations from its columns. The three systems are those of Chenard and Walcker, Wilson and Pilcher, and F. C. Blake, and these are diagrammatically shown for purposes of comparison by Figs. 159 to 161; all these employ but one vibrating trembler. In the first of these, one coil, one condenser, and one trembler serve for two cylinders; in the second, four coils, one condenser, and one trembler are used for four cylinders; and in the third, a single coil, with its trembler and condenser, serves for four cylinders. In the majority of cars, one coil, one trembler, and one condenser are necessary for each cylinder. A multiplicity of tremblers is objectionable, because each one is liable to have its own particular speed of vibration, and that since the moment and intensity of the spark depends upon its movement, the relative time at which the explosions occur may differ materially. In many ordinary commutators, in which one cam operates two or more contact springs successively, it is almost impossible for the contact points against which the springs are pressed to remain in correct adjustment relatively to one another, apart altogether from the consideration that the contact services of some may be cleaner than those of others. In the three systems here dealt with the commutators are so designed that careful machining is all that is required to enable absolute

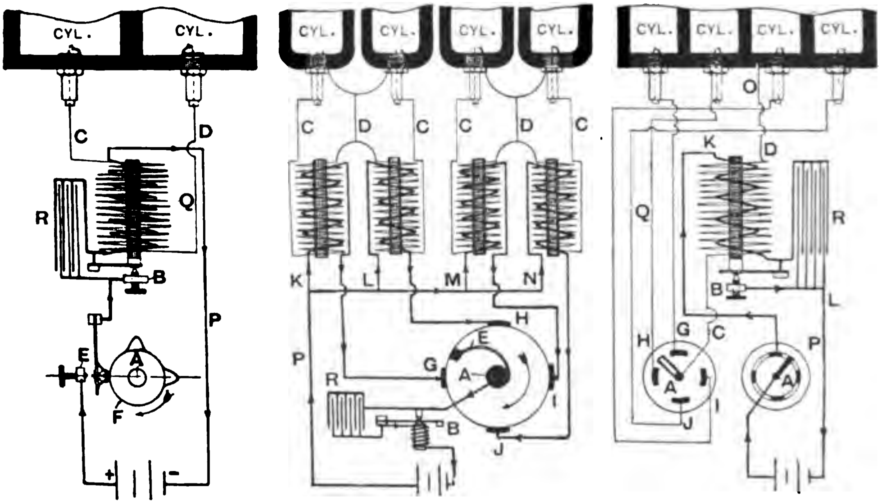


Fig. 159. Fig. 160. Fig. 161.

Figs. 159 to 161.—Chenard and Walcker, Wilson and Pilcher, and Blake Ignition Systems.

accuracy to be attained. In Figs. 159 to 161 the cylinders are represented by "Cyl.," the commutator spindles by A, the tremblers by B, the high-tension wires from the coils by the letters C and D, primary by P, secondary by Q, and the condensers by R.

In the Chenard and Walcker ignition system (Fig. 159), a single induction coil, fitted with its own trembler, has two secondary terminals, C and D, connected to the insulated portions of the two ignition plugs. The current from the battery is led through a "making and breaking" device, E, in the commutator, which is operated by the two projections shown on the cam F. The primary circuit is thus completed when a spark is required in either cylinder, and since the current flows from plug to plug through the cylinder casting both sparks occur simultaneously, although only one at a time is really required. In this system synchronism depends upon the proper construction of the cam F and its projections ; any lag which may be introduced by the coil, its trembler, or the contact maker being common to both cylinders.

In the Wilson and Pilcher ignition system (Fig. 160), the primary windings of the four coils are alternately connected with the battery through an independently operated trembler, which is worked by a small electro-magnet, and is provided with a condenser. The commutator is represented diagrammatically in Fig. 160, where A is its half-speed shaft, E the revolving contact spring, and G, H, I, and J are the four stationary contact blocks against which E presses. Separate wires lead from each of these contact blocks to one end of the primaries of the respective coils, and the wire from the other terminal of the battery branches to the other ends, K, L, M, and N, of the primary coils. The high-tension connections from the coils to the plugs are as usual, C showing the four insulated terminals, and D the earthed wires. Synchronism depends entirely upon the similarity of the four coils and upon the proper construction of the commutator.

In the Blake ignition system, Fig. 161, an ordinary coil with trembler and condenser is used, and the commutator automatically connects the battery with its primary terminals, K and L, each time that the spark is required in any of the cylinders. The commutator spindle A also drives a high-tension switch connection, which alternately puts the insulated secondary terminal C in electrical communication with the four ignition plugs, through the contact blocks G, H, I and J before the primary circuit is completed, and does not interrupt them till after the primary connections are broken. The secondary wire D is earthed as usual ; O shows the common wire. The Holden and Bolide systems are very similar.

Improvements on existing systems of electric ignition are admissible on two lines—automatic timing and automatic consumption of current, according to Capt. Longridge, who holds that the timing of the spark should adjust itself automatically to the speed of the motor, for with early ignition there is injurious strain on the engine, probable heating of the crank-pin, and undue wear on the crank-shaft bearings, and with late ignition there is considerable loss of power, high exhaust pressure, with increased strain on the exhaust valve gear, incomplete combustion, sufficiently prolonged, perhaps, to cause gradually burning of the valves, and possibly back-firing of the fresh charge. It might be well to so dimension the compression chamber and stroke as to produce at the dead points slightly more compression than it is intended to use for the explosion, thus allowing the crank to pass the dead point and gather way before the mixture is ignited at the working compression point. In any case, efficient running greatly depends on accurate ignition. At present timing is mostly left to hand regulation by the driver, but attention is now being given to automatic spark controllers, one of which is illustrated at Fig. 162. Here the fibre contact-breaker disc B is mounted on a sleeve V, rotatable round the motor shaft A. As the speed increases the centrifugal masses P and P^1, pivoted on the studs D, are forced outwards, causing partial rotation of the toothed sectors. The two-sectors thus advance the position of the disc, so that the brush M establishes earlier touch with the contact plate C.

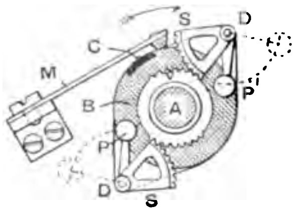


Fig. 162.—AUTOMATIC SPARK CONTROLLER.

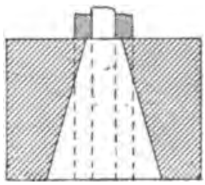


Fig. 163.—SECTION OF IMPROVED CONTACT BREAKER.

Automatic regulation of the current is of chief importance where accumulators only are used. At present the circuit is usually made by a brush brought in touch with a contact piece on a rotary disc. If this contact piece is of sufficient width for high speed, it will pass more than sufficient current when the speed is reduced. To obtain automatic regulation of the current and of the time of sparking, Captain Longridge suggests using wedge-shaped contact pieces on the rotating disc, and allowing the disc, under the direction of a governor, an in-and-out movement on the shaft (*see* Fig. 163). As the motor speed increased, the disc would slide, say backwards, bringing the wider portion of the contact pieces under the brush; as the speed decreased the reverse would take place. This would give increased contact surface and earlier firing for high speeds, with lessened surface and later ignition for slower speeds.

In the system of ignition by incandescent tubes and burners, a small hollow tube is placed on the bottom of the explosion chamber. After the exhaust a certain quantity of burnt gases remains on the bottom and in the tube itself. After admission of the new gases, and during compression, the mixing of the two kinds of gas is slight, and the explosive mixture does not come into contact with the tube. It is only when compression is at its maximum, and the inert gases are driven to the end of the chamber, that the gas reaches it, and the explosion occurs. By pushing in the tube more or less the motor can be regulated for various degrees of compression. Sometimes the tube is made of porcelain or nickel, but generally it is of platinum, which does not oxidise or alter its shape in the fire, and has the valuable quality, when once made red hot, of remaining incandescent in contact with hydrocarbons. These advantages discount its high price, from which, besides, the sale price of old tubes must be deducted. Nickel is one-fifteenth the cost of platinum, but lasts only three or four months. The ignition tube is fixed on the cylinder by means of a little collar

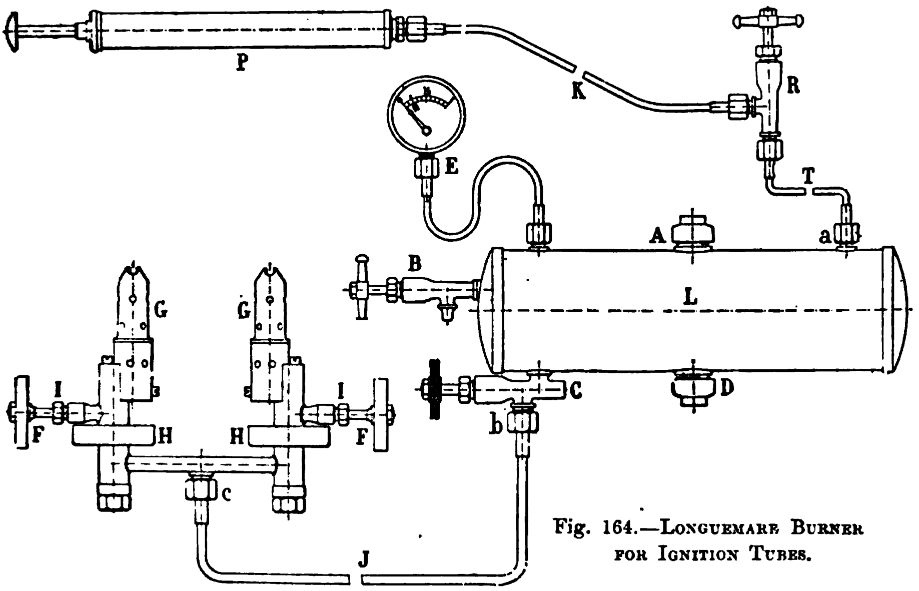


Fig. 164.—Longuemare Burner for Ignition Tubes.

tightened against a tube holder, screwed in the breech by a cap nut, the bottom of which is furnished with asbestos washers. Owing to being carbonised, these washers must frequently be tightened and replaced. The Léon Bollée firm has introduced a new joint without asbestos, which is thought to be very good.

The burners which heat the ignition tubes to incandescence and maintain them so are of various types. It may be useful, in order at a given moment to accelerate their combustion, to furnish them with a tube and an indiarubber pear or ball to blow air into them. Sometimes the tube is wrapped round with a nickel wire 0·5 mm. (0·02 in.) in diameter to keep its temperature high enough to relight the burner when suddenly extinguished.

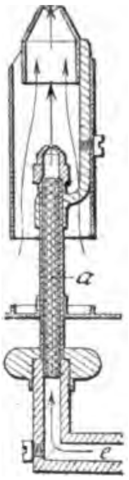


Fig. 165.—Bollée Burner.

The Longuemare burner (Fig. 164) is well known; it is started by igniting the alcohol, of which the cups H are about one-third full. The pressure of compressed air admitted by pipe K into the petrol spirit tank L should be about 1 kg. per cm.^{2} (14·2 lb. per sq. in.). Burners G have each a blow-pipe with platinum tube. Sufficient air for burning the petrol spirit is drawn in automatically. Incandescence is regulated by taps F, which have an asbestos stuffing box I; a temperature of about 1,300° C. can be attained. The tank L, about 8 cm. (3 in.) in diameter and 30 cm. (12 in.) long, has a filling plug A, pressure gauge E, and emptying plug D, contains nearly 1 l. (1·76 pt.) of petrol spirit, and can feed through J two burners for eight hours. Air enters cylinder L through cock R and tube T. B is a gauge-cock. A new burner, introduced by Madame Vve. Longuemare, only needs a slight pressure for work. A stroke of the pump P, and a slight heating of the tube suffice to start it working, there being no need of an alcohol cup.

In the Bollée burner, Fig. 165, the tube *a*, which supports the whole, has inside it a cotton wick reaching not quite to the top, where there is a cap pierced with a very small hole and surrounded by a perforated sleeve. The burner is started by external heating. On the inlet tube *e* for the petrol spirit there is an air bell which impedes movement in the column of liquid during motion of the carriage.

The Guillou incandescent tube is heated by an alcohol burner which consumes about 1 l. (1·76 pt.) in 20 hours. The burner, chimney, inspection chamber, and vaporiser are made in one piece, and into this slides a porcelain ignition tube which makes a gas-tight joint with a connection fitting, which fixes into the cylinder wall. The ignition tube and burner can be removed without the use of tools by loosening a thumbscrew. The moment of ignition has to be regulated once and for all to suit the motor by placing a greater or less number of displacement pieces in a side chamber branching from the passage between the cylinder and the ignition tube.

A comparison of electric and incandescent tube ignition shows the advantages of electric ignition to be as follow. Its starting is instantaneous, and if ignition is at a minimum advance, cannot be accompanied by an adverse explosion produced before the piston finishes its compression stroke. Extinction is also instantaneous, and it is possible to put on the brake by compressing the cylinder charge which for the purpose is prevented from exploding. Owing to the absence of burners, there is less danger of fire. There is surer ignition when the spark issues well into the mixture. Even if compression is slight, still the motor works, and consequently the car can be run at a slow rate of speed, whereas with burners if the compression is so slight as not to bring the new gases into contact with the tube, running is impossible.

Electric ignition makes it possible for the moment of ignition in a petrol motor to be advanced when such is desirable to suit different conditions with regard to the carburetted mixture. Transmission of the combustion in the carburetted mixture is not so rapid as might be thought; if ignition occurs at the moment when the piston is at the extreme point of its stroke, that is when the crank pin is at the dead point, combustion when the mixture is too rich has not time to be complete, and the total expansive power of the mixture is not obtained in useful work. It is better, then, for ignition to occur a little before the end of the compression stroke. The sparking cam is arranged so that with a minimum advance the spark occurs just before the end of compression; with a maximum advance the spark is not given before the commencement of the second half of the compression stroke. With electric ignition, irregularity is found to be due mainly to short circuits in the battery, accumulator, or conductors, rupture of a wire, or failure of the contact-breaker. Other inconveniences are expense, and the weight and bulk of the necessary apparatus.

Ignition by incandescent tube has been considered as less delicate but surer than electric ignition. The fuel for the burners is petrol spirit—ordinary motor spirit—and so there is not any separate source of energy to be maintained. Some drivers, however, carry a separate supply for the burners. Tube ignition makes it possible before starting to heat the air for the carburetter, a valuable advantage in winter, and these are all valuable qualities. No doubt extinction of the flame and consequent failure of the ignition are not impossible, but a long test shows these incidents to be rare. Consequently the addition proposed by Clément and Michaux must be considered useless. Their device produced a series of electric sparks inside the burner to keep it alight in spite of wind. The necessary dynamo employed by these inventors would cause a complication out of all proportion with the result to be obtained. Besides the possibility of extinction and the length of time (some minutes) required for starting, tube ignition may be said to have the following inconveniences. Tubes heat the cylinder, whilst the constant endeavour is to keep it cool with water; if the cylinder is air cooled simply by aid of wings, the heat of the burners is prohibitive and electric ignition must be adopted. Burners are a source of danger of fire. Baudry de Saunier mentions, in particular, that the petrol spirit may, at the instant when the burners are ignited, enter them too quickly, and if the burners are not hot enough to vaporise it, the spirit may burn and perhaps set the car alight, this being the case especially with pressure burners. It is possible for tubes to ignite the charge at the wrong moment, whilst the piston is moving backwards to compress the mixture; then the piston is driven violently forwards, giving all the mechanism a shock which may endanger the driver. The burners consume and thus waste fuel during stoppages, this being particularly inconvenient in the case of cabs on public service. With these last, electric ignition seems to be essential, and preferably the rupture spark is employed, this alone being strong enough to burn off the oil and carbonaceous dust which is deposited on the sparking plugs when the work of the cylinders is only intermittent, but the rupture spark generally necessitates the employment of a dynamo. In such circumstances Forestier asks whether, since with a dynamo it is possible to heat the carburetter electrically, it would not be well to employ petroleum, which is cheaper than petrol spirit, to drive the public cabs.

Methods of ignition other than the electric spark and incandescent tube have been tried. The Gans de Fabrice igniter is an imitation of Paquelin's thermo-cautery, which consists of a tube of spongy platinum, on the inside of which a mixture of hydrocarbon vapour and air is blown constantly. This igniter gives a very high temperature, which was brought accidentally to notice in some experiments by the platinum melting, where feeding was continued too long. Dr. Gans de Fabrice concluded from his studies on petrol motors that there is a somewhat close relationship between the explosive force of the mixture and the temperature of the body producing it, and that for this reason his igniter should give better results than tubes or electricity, the temperature being higher than either. He considers that the motor efficiency would be increased by from 30 to 50 per cent., which, however, seems impossible; and at any rate his igniter has not been tested on an automobile, it is thought.

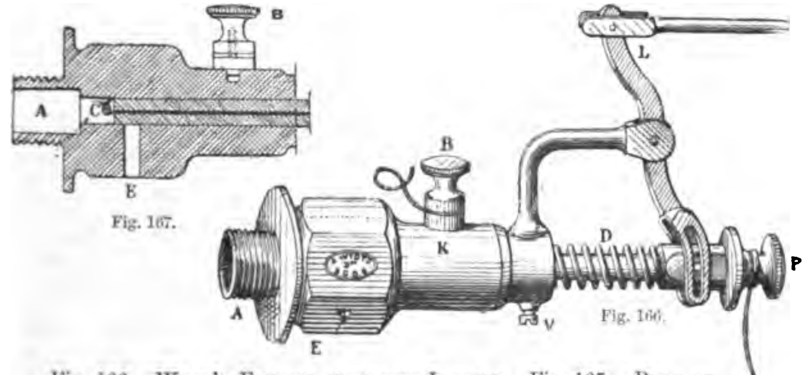


Fig. 166.—Wydt's Electro-catalytic Igniter. Fig. 167.—Plug of Wydt's Igniter.

Wydt's electro-catalytic ignition device is a recent invention embodying a simple principle. The igniter consists of a fine spiral of osmium wire (C, Fig. 167) mounted at the end of a plunger which is capable of movement inside the sleeve K (Fig. 166). This sleeve, by means of the threaded end A, screws into the motor cylinder. The plunger is of insulating material, and carries a central conductor, ending in a binding screw P, there being another such screw at B. The ends of the osmium spiral, C, are connected to the central conductor in the plunger and make contact with the inside of sleeve K; thus when the battery current is switched on the osmium wire is heated to incandescence, causing the ignition of the charge in the motor cylinder combustion chamber with which A is in communication. This suffices for starting the motor, but after a few explosions have taken place the current is switched off, and the osmium wire continues to glow owing to the action of the combustible gases. The lever L enables the position of the plunger, and consequently that of C, to be varied, it being pushed in or out against the action of the spiral spring D. By this means the instant at which ignition takes place may be advanced or retarded, since when the plunger is withdrawn a longer cushion of burnt gases intervenes between the charge and the igniting wire. When the plunger is brought far enough back to disclose port E, cold air enters on the induction stroke and cools the osmium wire and stops the motor, thus providing a ready means of bringing the motor to rest.

The Bernardi system of ignition is based on the catalytic property of platinum; this metal becomes incandescent when dipped in a mixture of air and combustible gas. Instead, however, of employing spongy platinum, which is very delicate, and requires a bright red temperature to ignite with certainty a compressed explosive mixture, Bernardi employs a platinum wire tissue, which ignites at dark red heat, that is at about 250° C. Ménard employs a bundle of platinum or nickel wires, which can be pushed to various depths in the cylinder, so as to regulate the time of ignition.

Sometimes the mere work of compression, after the motor has been started, is employed to maintain the temperature of an ignition tube sufficiently high to cause explosion of the charge, thus rendering ignition automatic. Banki and Csonka, Latapie de Gerval and Southall proposed devices having this principle. Practical devices of this nature were in use by the Société des Moteurs Benz, and by Loyal. In Loyal's two-cycle-motors, at starting the nickel tube is heated by a Longuemare petrol lamp. Banki and Csonka recommend heating the new gases by running them through a worm bathed by the exhaust gases, but most of the automatic systems of ignition can dispense with this precaution. The Diesel motor has automatic ignition, and as it compresses only pure air, in this case the process is not attended by the risk of premature explosion, which in some other cases may be very serious.

The cylinders of petrol motors will now be considered. Generally two cylinders are employed, though for a small power motor a single one will suffice; often, however, three or four cylinders are combined, as in the majority of modern high-power motors.

Three-cylinder motors are employed on the Brooke, Duryea, and a new type of Panhard car, and some engineers claim special advantages for them; but the matter is mainly one of balance and the suppression of superfluous vibration, in which matter the three-cylinder motor must be inferior to the four-cylinder one and superior to motors with one or two cylinders only. It is obvious that a suitable arrangement of the cam shaft will cause explosions to occur at regular intervals, so that in a three-cylinder motor an impulse is given to the crank-shaft at every two-thirds of a revolution, the cranks being at angles of 120° from each other. By employing similar means the four-cylinder motor can be made to give one impulse every half-revolution, the cranks being at 90° from each other. In both cases the crank chamber pressure remains approximately constant, and consequently there is no ejecting action upon the lubricating oil. In a two-cylinder motor the best that can be done to obtain regular work is to set the crank pins in line with one another, but this regularity is often sacrificed in order the better to balance the moving parts and to maintain a constant pressure in the crank chamber.

Petrol motor cylinders may be vertical, horizontal, or inclined; this last position was adopted in the primitive Daimler, where the two cylinders were placed, one on each side, at 15° from the vertical, and it was invented to regularise the action of the motor by preventing the times of the dead points from being the same in both of the pistons. It was abandoned, as it complicated construction without really profiting the regulation; but the modern Ader and Cotterau motors (pp. 271 and 272) approach this design. The advantage of horizontal cylinders is that during running their vibrations agree with the motion of the car, though there is the inconvenience, especially on a steep gradient, of the start being too sudden. The great defect of these cylinders, however, is that they become oval, and require reboring. Vertical cylinders are free from this last defect, but their vibrations are in a direction which does not agree with the movement of the running vehicle. Cylinders are of steel or soft cast-iron; steel cylinders range in thickness from 2 mm. to 3·5 mm. (0·08 in. to 0·14 in.) for motors of from 65 mm. to 90 mm. (2·5 in. to 3·5 in.) bore, whilst for the same conditions cast-iron cylinders have a thickness of from 4 mm. to 6 mm (0·16 in. to 0·24 in.).

For petrol motor cylinders Prof. Hiorns inclines to white hematite, cast in metal moulds, or, as a cheaper alternative, he and Prof. Turner recommend the closest and hardest iron that can be conveniently machined, such as combined carbon 0·55, silicon 1·8, sulphur 0·1 or less, manganese 0·5, and phosphorus 0·75. The casting of a cylinder, where there is any intricacy of design, should be a matter for special precautions. While it is not practicable to employ a system of fluid compression, such as the Whitworth or the more recent French Harmet system, some equivalent should be sought by insisting on adequate head. In view of the troubles arising from porous cylinders and for other reasons, Captain Longridge favours the substitution of steel tubes for cast-iron cylinders. For small cylinders, steel has the merits of lightness, strength, freedom from flaws, easy cooling, and perhaps cheapness. Steel tubes screwed into a cast-steel, pressed steel, or cast-iron head should make a good job. The Holden cycle motor has steel-tube cylinders, in which 0·35 per cent. carbon is present. The cylinders of the Victoria bicycle motors are bored from the solid steel bar, the radiating fins being turned in the lathe. The Centaure motor had thin wrought steel cylinders, but in the latest type they are of cast steel (*see* p. 216). Perhaps solid drawn steel tubes are best of all, being the strongest and most reliable, but cast-iron piston rings might be retained. These should be of strong, fine-grained elastic iron, of approximately the following constitution: Combined carbon, 0·5; silicon, 2; sulphur, 0·1; manganese, 0·5; and phosphorus, 0·8.

The cooling of cylinders is a most important subject. The temperature of the charge during explosion is very great, Witz estimating it at not less than 2,000° C. No doubt the temperature is decreased very soon by expansion of the gas, but even lessened in this manner it would have disastrous effects, unless special provision were made. Without some system of cooling the cylinder it would be impossible to ensure lubrication of the cylinders, because the most heat-resisting oils are decomposed at 300° C., and above that produce detrimental carbonaceous deposits which interfere with the working of the valves and of the motor in general. Very great and unequal degrees of expansion in the carefully adjusted parts of the cylinder and piston would impede working. Wedging of the piston, seizing of the connecting rod and crank, might be feared, and the valves, especially the exhaust, put out of working order (two hours' work at too high a temperature suffices to cause this). To avoid all this, some system of cooling is necessary, and the necessity of this, it can be understood, is a source of considerable waste of energy, represented by the heat units of the fuel, and it constitutes one of the grave defects of existing petrol motors. Consequently cooling must be accomplished only in the least possible degree, though this last has not been determined precisely. As a rule, cooling is not excessive in automobile motors, because the renewal of the water used for the purpose is shirked as much as possible.

To accomplish the cooling of petrol motor cylinders, generally a current of water is circulated around the combustion chamber, the valve boxes, or even all the cylinder. The water is kept in motion by aid of a special pump or merely by the differences of density produced in itself; thus there is the great inconvenience of frequently renewing the water in the tank, especially during summer. To prevent too rapid heating of the water, it is run through pipes or coils, between which a rapid current of fresh air is driven by the motion of the car. P. Royer has proposed to replace the leather or wooden mud-guards of cars by flanged tubes in which the water could circulate and be cooled. J. Dupont employs a special vessel furnished with flanges. Lepape has tested a number of systems of cooling the water, particularly that in which the water, after it has flowed around the cylinders and carburetter, ascends to the top part of the cistern and then falls in rain on four inclined sheet-iron planes, a current of air there blowing through the liquid spray and separating the steam. Lepape also has tested a system in which is used sail cloth like that employed by firemen to make their buckets. In his opinion the permeability of this material has the double advantage of increasing the liquid's surface of contact with the surrounding air and of allowing the steam to separate from the liquid. The process of cooling the water, almost universally employed, consists in running the water through straight tubes between two collectors for entrance and exit of the water, partitioned in such a manner that it flows through the pipes in series or in a worm at several levels. These tubes or radiators have flanges, which increase their surface of contact with the air which cools them. One of the most common types is that of Grouvelle and Arquembourg, who employ tubes having a bore of 15 mm. (0·6 in.) for motors of less than 8 h.p., and tubes of 18 mm. (0·7 in.) for motors of greater power; the tubes are of copper and have iron or aluminium rectangular flanges, 35 mm. × 45 mm. (1·4 in. × 1·8), jointed or soldered to them, these flanges being from 60 mm. to 70 mm. (2·4 in. to 2·8 in.) apart. It is estimated that 2 m. (6·5 ft.) of tube 15 mm. (0·6 in.) diameter, or 1·35 m. (4·5 ft.) of tube of 18 mm. (0·7 in.) diameter, are required per h.p. These tubes weigh, per metre (39·4 in.), the first 875 g. (31 oz.), with aluminium flanges, and 1·275 kg. (45 oz.) with iron; the second 1·22 kg. (43 oz.), and 1·820 kg. (64 oz.) respectively. From these

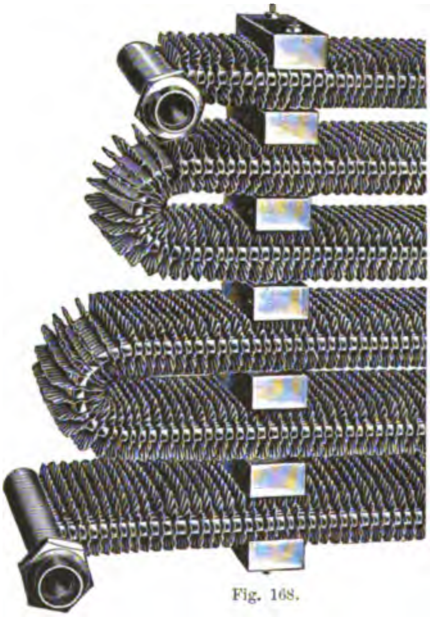


Fig. 168.

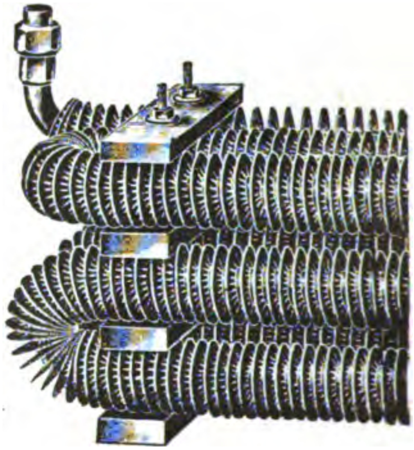


Fig. 169.

Fig. 168.—Loyal Radiator.
Fig. 169.—Sauerbier Radiator.

figures it can be seen that the weight of a radiator cannot be neglected; cost also is considerable, this amounting to about 8s. per metre of 15 mm. (0·6 in.) tube fitted with iron flanges (about 2s. 7d. per ft.). However, the distance a car can run without requiring cold water can be greatly increased, provided there is a good draught of air, by employing a well-arranged cooler, that is to say, one with flanges parallel to the longitudinal axis of the car. This distance may be reckoned as 200 km. (124 miles), at an average speed of not more than 20 km. (12·4 miles) per hour; this is a ten-hour run, but it is well to obtain new supplies of water oftener if possible. Loyal gives the flanges a corrugated form, so that their surface contact with the surrounding air is increased, as is also their rigidity, and Loyal's new radiator, as employed on Decauville and other cars, has a number of small bore tubes, perhaps as many as twelve, placed side by side, and at first sight appearing to be one wide flat tube; these are held together by big corrugated flanges, as shown in Fig. 168.

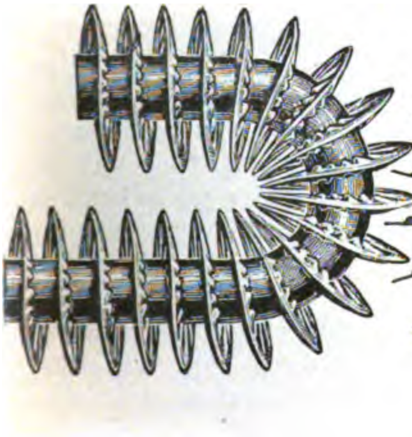


Fig. 170.—Part of Sauerbier Radiator.

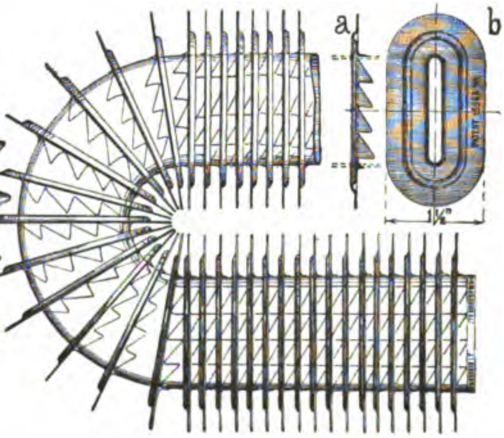


Fig. 171.—Begbie-Audin Radiator.

Julien holds the opinion that in radiator tubes of circular section, contact of the inner side with the central veins of water is difficult. For radiators he adopts flat flangeless tubes, having round ends, to facilitate joining with the collectors or pipes, and he makes the logical proposal to fix a series of tubes, branching from the motor cylinder, and parallel with it, so that the water in this jacket may cool in passing through these tubes. Julien also constructs a cooler, formed by a water-tube of wide and very flat rectangular section coiled in worm form, the narrower the tube the greater being the number of the coils. The tube is placed on the car with its mouth in front, so that an abundance of air can enter between the coils and escape through two lateral orifices.

More modern radiators than the above (excepting the new Loyal radiator, Fig. 168) are those of Accles and de Veulle, Albany, Begbie-Audin, Sauerbier, Mercedes, Gillet-Forest, Ramier-Marchal, and others. That of Sauerbier (Figs. 169 and 170) has gills formed by a continuous helix of thin copper wound round a tube of circular section. The strip of copper is corrugated along one edge, and so caused to assume a spiral form; it then is threaded over the tube and soldered in place. The Begbie-Audin radiator has a flattened central tube as in Fig. 171, and the oval sheet metal flanges are so cut as to form teeth, as illustrated, acting as distance pieces between the flanges, and assisting the soldering. The water in the flat tube forms a thin sheet. In Fig. 171, *a* is a side view of a flange, and *b* a front view. Many other new radiators have flat tubes; the Albany, for instance, has very flat and thin tubes, the radiating flanges being corrugated strips of copper, soldered as in Fig. 172: this acts as a radiator for petrol cars or a condenser for steam cars, and there is a horizontal type with the tubes placed at an angle to meet the opposing air. The new Napier car employs an Albany radiator with a chain-driven suction fan behind it. The Accles and de Veulle radiator is a circular tube with star fins or flanges (see Fig. 173), and for a 6 h.p. motor has a weight of 5 kg. (11 lb.). The Ramier-Marchal device is one of the few in which gills or flanges are not used, and is extremely simple. Thin metal tubes, fluted or corrugated, are mounted horizontally between two standards, as in the end view, Fig. 174; as usual, the hot water enters at the top, and the cooled water flows through a pipe at the bottom. Another radiator with flangeless tubes is the Gillet-Forest, which is shown in the scheme of cooling illustrated by Fig. 175, p. 198. This radiator is claimed to be a mere condenser of steam given off by the water in the motor jacket. The float device A (Fig. 175), fed from the water tank, maintains a constant water level in the jacket B of motor cylinder C; the steam as it rises passes into the radiator or condenser D, and fills the middle three vertical tubes and the top horizontal tube as indicated; stops or partitions in the lower horizontal tube E prevent the condensed water which dribbles down the remaining tubes from directly joining the water in the jacket, and tubes F conduct the condensed water to the pipe supplying the underside of the cylinder jacket. The condenser tubes are about 25·4 mm. (1 in.) in diameter, and are of brass. Outwardly the Carpentier-Meunier radiator resembles the Gillet-Forest, the tubes being vertical and communicating top and bottom with the main horizontal ones. But the tubes have plain square gills forced upon them, instead of being crinkled as in the type last mentioned; both types, however, form a V in the front of the car, and in many opinions enhance the general appearance, the Gillet-Forest being particularly smart and well finished. The Duryea device is a condenser rather than a cooler; a tank with horizontal tubes passing through it on the principle of a marine condenser is placed at the back of the car (see p. 653), and this quite replaces the radiator used on more usual types of car. Air passes through the tubes in the tank and cools the water somewhat, but it is the open claim of the Duryea firm that it is not desired to make the water cold, as the engine is run at as high a temperature as the limits of lubrication will allow.

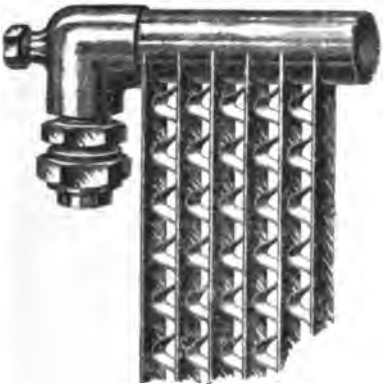


Fig. 172.—ALBANY RADIATOR AND CONDENSER.

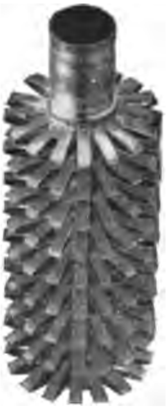


Fig. 173.—ACCLES AND DE VEULLE RADIATOR.

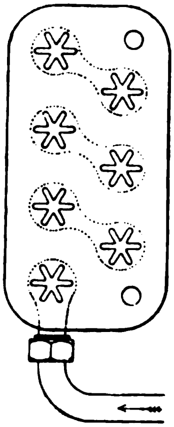


Fig. 174.—RAMIER-MARCHAL RADIATOR.

The multitubular radiator, known in France as the "nids d'abeille," in England as the "honeycomb" radiator, and also fairly generally as the Mercedes radiator, is quite a distinct type, originating with the German Daimler firm; its efficiency is marked, and many of the leading makers have already adopted it in some one of its modifications. Essentially it is an upright metal box, 7·6 cm. (3 in.) or more thick, pierced from side to side by small tubes with open ends (the Mercedes radiator may contain about 5,000 tubes). These tubes in section may be square, as in the Mercedes, triangular, lozenge, round, flat, and elongated, or of a shape suggesting the water tubes in the Ramier-Marchal radiator (Fig. 174). One type is built up of tubes originally shaped as in Fig. 176. These tubes have their ends expanded and a slight lip formed on each side, as shown in Fig. 177. Then they are nested together and soldered at their ends, probably by first tinning them and then dipping in molten solder. The expanded ends and the side lips cause a space to exist round each tube, and it is this space that the water ultimately occupies. The space is so small that, on looking at the face of a radiator, it seems impossible for it to contain a drop of water. The tubes are built up in sufficient number to answer the purpose of radiator and tank in one, the water of

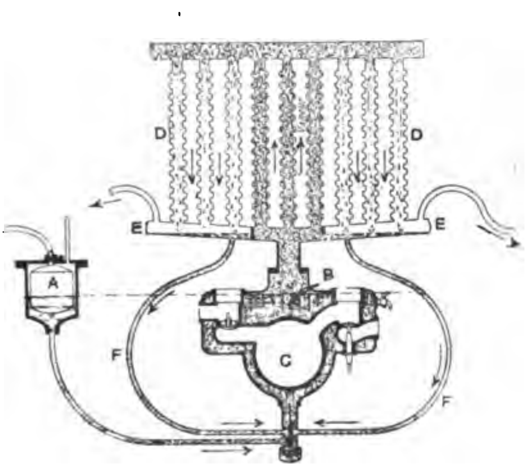


Fig. 175.—Gillet-Forest Water-cooling System.

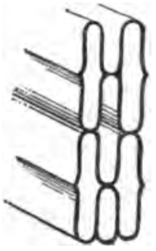


Fig. 177.

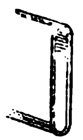


Fig. 176.

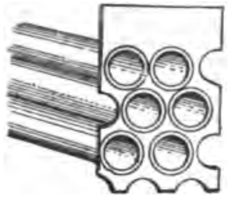


Fig. 178.

Figs. 176 to 178.—Parts of Multitubular Radiator.

course being split up into an almost countless number of thin films in constant contact with the tubes, through which, when the car is in motion, the air is constantly rushing; though generally a fan, driven direct by the motor shaft, revolves close to the inner face of the radiator, and assists in drawing the cool air through the tubes. The fan may be discontinued, perhaps, at high speeds and against strong winds. When the star-shaped tubes, already referred to, are used, their ends are expanded to form a square suction, and on soldering these ends together a very efficient type results. It is usual when employing tubes of any other of the shapes mentioned above to expand them at each end into metal plates which form the sides of the box; Fig. 178 makes the principle of this clear. This method gives greater capacity as a tank, but almost surely a lower efficiency as a cooler. Three typical multitubular radiators are shown in Figs. 231, 632 and 663, pp. 250, 585 and 617.

The use of a pump may be necessary to make the water flow in the radiators. Though the alternating pump is not without precedent, the rotary pump is usually adopted, especially the centrifugal, which needs no valves and has very simple mechanism. Grouvelle and Arquembourg construct a pump 125 mm. (4·9 in.) in diameter, the entrance and exit orifices being 15 mm. (0·6 in.), weighing 1·8 kg. (4 lb.), and making 1,500 and 2,800 revolutions per minute. Dalifol and Thomas construct the Abeille pump, which normally revolves at the rate of 1,500 revolutions per minute, and can be inspected without touching the piping by simply unscrewing a plate fastened with four bolts. Benoit and Julien employ a cast-iron cylindrical body closed by two plates, inside which revolves a cast-iron screw having two opposite threads separated by vertical partition; the water arrives at the exterior of each thread, travels towards the central partition, and leaves the pump perpendicularly to its axis. Normally it works under pressure, but once primed it can suck water from a depth of 60 cm. (24 in.); it weighs 3·5 kg. (7·7 lb.), and with a velocity of 2,000 to 2,400 revolutions it delivers at a height of 1 m. (39·4 in.) from 500 l. to 600 l. (110 gal. to 132 gal.).

The inconveniences which would result from not cooling the cylinders have been mentioned, and it may be remarked that sudden cooling (caused, for example, by admitting too much cold water into the pipes during the journey) would not be advantageous either. It would cause condensation in the cylinders, and the petrol spirit now in liquid form would fill the ignition tubes, so as to prevent the new gases from coming into contact with them, or cause short circuits in the sparking plug; in both cases the motor would cease to work. It might also cause the cylinder joints to break or the cylinder to crack, and in both cases water would be allowed to enter the cylinder. Flow of water cannot take place around the cylinder without the deposit on the walls of the jacket of calcareous substances which decrease the conductivity of the metal. It must be possible to frequently clean the insides of the cylinders, and so the jacket must be easily removed. In spite of all these preparations the employment of water is very inconvenient, and fortunately can be dispensed with on small motors. There is also the great disadvantage in winter of the water readily freezing when left in a stationary car, unless about 20 per cent. of glycerine is added.

Small air-cooled motors are simply provided with flanges intended to conduct the heat to the atmosphere. The flanges are generally made of iron cast solid with the cylinder, but Moreau employs copper flanges, forced around the cylinder. In the Papillon motor the cylinder is surrounded by regular hoops of copper, which has more effect than iron owing to its conductivity being greater. In the Aster motor the copper flanges are corrugated, so as to increase their contact surface. Grivel experimented with aluminium flanges wound spirally around the cylinder. Bearing in mind that the radiating power of a body varies with the nature of its surface (a polished metal having a radiating power equal to 12 acquires an equivalency of 100 when coated with lamp black), Huber-Baudry has shown the advantage of painting petrol motor cylinders black or white; and there is something perhaps to be accomplished in this direction. However, it must be remembered that surfaces which radiate heat most readily also absorb it as readily. With adjacent flanges it is perhaps to be feared that the heat given off by one will be absorbed by its neighbour. Then again, as far as can be judged from the necessity of renewing air around the cylinder, it is mainly by conductivity that cooling takes place, and so in rendering the surface of the motor rougher the paint must not interfere with this circulation. Preference must be given to the Sire process, by which the cylinder parts are given an electrotype coating of unpolished 'copper, the greater the need of cooling the thicker being the copper. The copper will acquire a higher temperature than the lamp black, and the heat will be so much the better diffused, as the surface of the cylinder is at a greater temperature than the surrounding air.

The Lanchester method of air-cooling is applicable to even high-power motors. Two aluminium fans are friction-driven by the fly-wheel between them, and suck the air from between the flanges cast on the two cylinders into the wind chest and thence into the centre of the fans, the air then being ejected by centrifugal force at the periphery. The fans consume but little power, and discharge the heated air quite away from the motor. Wind-scoops (see p. 678) at the side of the car assist the fan action. This method replaces that in which a fan sent a forced circulation through an air jacket round the cylinder, the heated air then passing to the carburetter (that also was the Diligeon method). Now air is taken from, not to, the Lanchester motor.

Various methods of cooling petrol motors have been proposed by G. Desjacques, Klaus, Lepape, Diligeon, Dufour, and Goret. Desjacques proposes that small holes be made in the wall of the cylinder parallel to its bore, so as to form passages through which the air can circulate close to the parts to be cooled. Klaus makes the exhaust gases act on the flanges, so as to cause a stronger draught of air around them, but it would be better, it seems, to keep them out of contact with these gases, which at leaving the silencer are still very hot, and to employ them to produce a current of fresh air around these flanges, as suggested by an inventor who made a helicoidal groove in the cylinder jacket. Lepape has adopted this device in some of his cars, the vertical motor placed in the front being enclosed in a casting in which the exhaust gases produced a draught of fresh air. Usually these gases have a pressure of from 3 kg. to 4 kg. per cm.^{2} (43 lb. to 57 lb. per sq. in.), and it is evident that such a pressure can be taken advantage of. Dufois, in his two-stroke-cycle motor, uses a pump worked by levers and a cam mounted on the shaft governing the exhaust ; the pump sends water to the inside of the cylinder itself, where the action of the water is more effective than around the outside of the cylinder; but it is a question whether water can be collected and again employed, and whether the results compensate for the complication of the system. In the Goret six-stroke-cycle motor a draught of pure air is created in the cylinder after each explosion, and this fresh air cools the cylinder.

The Vilain method of cooling motor cylinders acts on the thermo-syphon system. A coil of copper tubing mounted above the top of the motor cylinder has its ends connected to the top and bottom of the cylinder jacket, the tubing forming a closed circuit, no reservoir being necessary. If the copper tubing has a radiating surface of ten times the surface of the cylinder walls, its radiating power when standing still is calculated to keep the temperature of the jacket at 128° C. (262° F.). A safety valve is fitted, and there is no evaporation, the water lasting indefinitely. About 4·5 l. (1 gal.) of water is carried.

The pistons of petrol motor cylinders are constructed very long, so as to be self-guiding; and sometimes they are prolonged by a hollow sleeve. They must be light, as heavy pistons more readily wear away the lower part of horizontal cylinders. Pistons are made of malleable cast-iron, and have grooves in which, to ensure tight fit, are lodged segments, these being rings of copper, malleable iron, or, better still, of ordinary cast-iron, a little greater in diameter than the cylinder, and as weak as possible, so as to be pliant. The segments should quite fill the width of the grooves, without, however, being tight, because this would destroy their elasticity; they should have a play of 1 mm. (0·04 in.) in the depth, so that they act as springs. To avoid the necessity of lubrication and cooling, Michelen proposes to lessen the friction of the piston by furnishing the latter with circular gullets separated by projecting parts slightly less in diameter than the cylinder. This piston would give so much greater tightness as it moved quicker, but it would have to be guided, as it would not touch the cylinder.

The connecting rod fixed direct to the piston works by its other end the motor crank shaft. It is usually attached to the piston by a pin which runs right through it, and is enclosed by the eye of the rod. Roser and Mazurier fixed the connecting rod to the piston by a ball and socket joint, which gives a greater surface of friction and but little wear, play being suppressed. In all cases the adjustment and lubrication must be perfect, so as to avoid seizing. The quicker the motor works the lighter must be the connecting rods.

To start a petrol motor, the piston is worked for a few strokes by means of a hand crank. With this object some cars are provided with a device to open the exhaust valve, to prevent compression of the gases found in the motor when at rest. The hand crank generally is fitted on a prolongation of the motor crank shaft, and so when the motor is once stopped the driver must leave his seat to start it again. This inconvenience is not great, because stoppage of the car is not followed necessarily by that of the motor, except when so required. Consequently, it is possible that complicated mechanism to enable the driver to start the motor from his seat may be found to be unnecessary. However, gear which can be started from the seat affords facility for preventing vibrations whilst stopping, and some cars with small power motors—amongst them the Decauville old type voiturette—are so provided.

Noise and odour emitted by petrol motors imply superfluous vibrations, defective combustion, and consequent waste of energy. On these two points petrol motors are deficient. Later, the question of vibration will be returned to, and for the moment attention will be given to the noise caused by the escape of burnt gases and to their odour. To decrease noise and, in consequence, dust, which would be raised by the jets of gas if they were free to come into contact with the ground, the burnt gases, on leaving the cylinder, are conveyed to an exhaust box or silencer, generally formed by a horizontal cylinder communicating with the outer air by a tube finely perforated. The gaseous mixture expands in the silencer and escapes in thin streams through the holes. To effectually deaden the noise the silencer must be large, and the perforations must be small and many; it may be—as in the Napier car—that two or three silencers in succession are necessary. Evidently all this somewhat decreases the power of the motor, which must overcome a pressure greater than that of the atmosphere to force the gases into the exhaust box. Muffler is a better name than silencer for the exhaust box.

The results of a competition of silencers, organised in March, 1903, by the French Automobile Club, are given in the table on the next page. The silencers were all tried on the same petrol motor, whose power was measured by coupling it to a dynamo and noting the amount of energy produced. Without any silencer attached, the output was 5,676 watts.

EXHAUST SILENCER COMPETITION.—A. C. F.

Name of Silencer.	Weight.		Relative Noiselessness.	Output in Watts of Petrol Motor coupled to Dynamo.	Percentage of Loss of Power due to Silencer Back-pressure.
	kg.	lb.			
Chapuis	—	—	13	4,140	2·7
Ossant Frères	10	22	12	5,040	11·2
De Retz	19·05	42	12	4,950	12·79
Motor Car	7·35	16·2	12	4,500	20·7
Ossant Frères	10·7	23·6	11	5,040	11·2
Rousseau	—	—	11	5,220	8
Megevet	—	—	10	5,220	8
Saint-Denis	—	—	10	5,310	6·4
Linzeler	—	—	10	4,680	17·5
Arnaud	—	—	8	5,175	8·8

Until recently the majority of the silencers or mufflers used have been absurdly small, giving rise to quite unnecessary back-pressure, and so wasting power. Therefore, on the Brooke, Mercedes, and some American cars, a bye-pass has been added to the exhaust pipe between the cylinder and silencer to free the exhaust when more power is required. This method, as applied to the Brooke car, is shown by Fig. 179. To ensure immunity from fracture in case of back-fire, a relief valve is sometimes fitted to the muffler. Some types of exhaust silencers are described below.

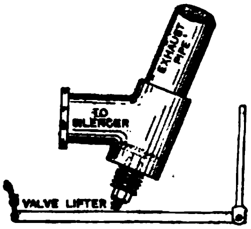


Fig. 179. — BROOKE EXHAUST RELEASE VALVE.

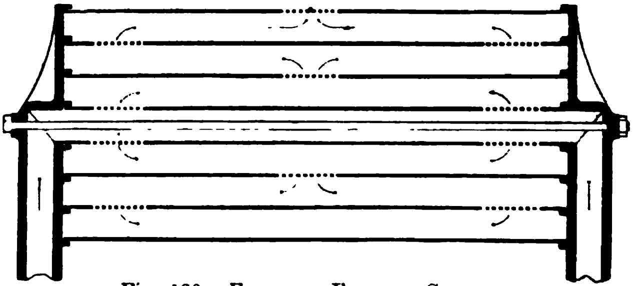


Fig. 180.—FRIEDMAN EXHAUST SILENCER.

The Friedman exhaust box (Fig. 180) is an interesting device. A number of concentric tubes or drums communicate with one another through the perforations indicated. The exhaust enters from each cylinder at opposite ends of the central tube, from which it diffuses outwards. As the exhaust gases from the two cylinders oppose one another in the inner tube, the noise is almost completely silenced. The exhaust finally escapes through holes in the outside or largest drum.

The exhaust box on the Autocar tonneau (American) is rectangular in section (see Fig. 181), and is composed of a number of flanged sections held together by bolts that pass the whole length of the box. There are sheet metal perforated baffle plates, and these project right through the walls of the box, so as to increase the cooling surface. It is connected by separate pipes to the two cylinders of a 10 horse-power motor, and the exhaust enters on the right side (in Fig. 181), and leaves at the other end, through the small holes shown. The size of the holes in the baffle plates decreases the nearer the plates are to the far end.

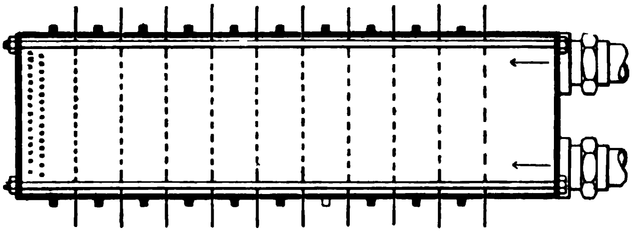


Fig. 181.—AUTOCAR EXHAUST SILENCER.

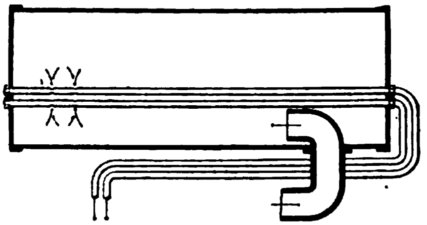
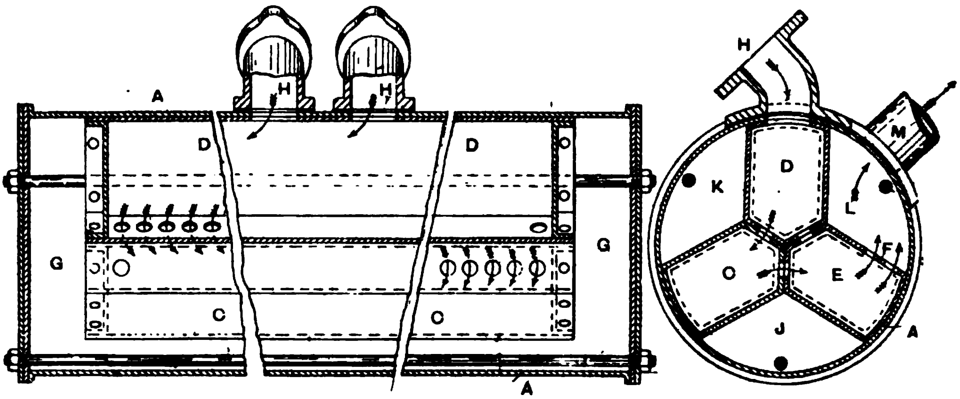


Fig. 182.—OLDSMOBILE EXHAUST SILENCER.

The Oldsmobile exhaust box (Fig. 182) is a successful device of ample size; it forms, in fact, quite a conspicuous feature of the car The exhaust gases enter the free space of the exhaust silencer and percolate slowly to the outer air through the two bent pipes perforated towards their left ends. The ample size and the gradual passage of the gases account for its efficiency.

The Prestwich-Drury exhaust silencer is a cylinder, A, Figs. 183 and 184, with removable ends: the closed tubes C, D and E are a little shorter than the cylinder so that a space G is left between their ends and those of the cylinder. These tubes are shaped to accommodate themselves to that of the cylinder, and they create passages (J, K, L) extending longitudinally. The exhaust gases are admitted near the centre of the cylinder, as at H, into one of the tubes and pass out through holes near one end communicating with the adjoining tube, which has holes communicating with the third tube. This has a number of small holes (F) communicating with one of the passages (L). After circulating in the outer passages, the now greatly expanded gases pass to the atmosphere through a pipe M, fitted near one or both ends of the cylinder A. Fig. 183 is a longitudinal section, and Fig. 184 is a cross section of the exhaust box.



Figs. 183 and 184.—Prestwich-Drury Exhaust Silencer.

The Wainwright exhaust silencer, patented in 1902, is a comparatively elaborate device; Fig. 185 shows a longitudinal elevation of the apparatus with certain of the parts in section. The exhaust is led from the motor by pipe A, which branches into B and C. Between the ends of B and C is a chamber D, whose size varies with requirements. This chamber is of double-conical form, the flanges at their bases being secured together by bolts or screws K. The bases E of the conical chambers have holes M, and inside the chamber D are a number of plates F, the conical perforations (G) in which are larger in diameter at the exit side. These perforated plates are supported on central bolts (H), whose external ends are preferably screwed into the end plates. The plates are kept the required distance apart by means of distance pieces or washers J. Another means of supporting the internal baffles may be adopted if desired. The exhaust gases flow through the pipes A, B, and C through the perforations in the plates F, and out through the perforations M in the chamber D to the atmosphere. In doing so the gases become broken up. The rain shields L, secured by bolts K, do not obstruct the passage of the gases, which pass through them in the direction indicated by the arrows.

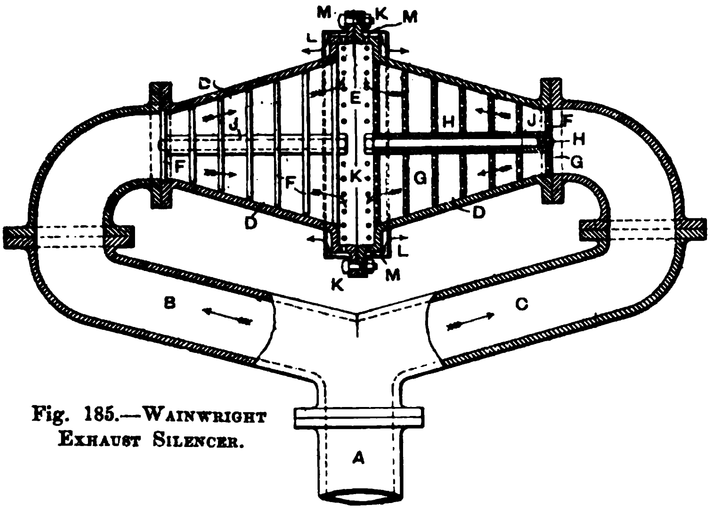


Fig. 185.—Wainwright Exhaust Silencer.

As a rule, nothing is done to decrease the odour of the exhaust, though Chevalet's suggested appliance diminishes both odour and noise. It should be mounted next to the exhaust box or on the exhaust pipe. It consists of some ring scrubbers, similar to those employed in gas works, furnished inside with a cast-iron plate perforated with holes and filled with shavings of wood, or, better, of iron. These superposed rings are wetted with water, or, better, with odourless oil, to arrest the unburnt oil or spirit which is the cause of the odour in exhaust gas. This oil can be used for lubrication when the impurities have been removed by decantation or filtration. The imperfect combustion of the charge is due largely to some portions of the carburetted air cooling and condensing on the metallic surfaces of the motor; perfect combustion would produce an odourless exhaust, and proper regulation conduces to this end.

CHAPTER VII.

TYPICAL PETROL MOTORS DESCRIBED.

THE elements of petrol motors having been dealt with in detail, an attempt may be made to describe some of the various types in actual employment on modern cars. A complete review of all is impossible, as they are legion, and new ones appear constantly; but the sixty or so described in this chapter are thoroughly representative.

It is vain to attempt anything more than a very general classification of modern petrol motors, particular classification being impossible. The last year has seen an attempt at standardisation, and now a number of leading motors conform in their essential features to one standard practice. As regards principles of operation, the vast majority work on the four-stroke-cycle, a small number on the two-stroke-cycle, and a very minor and, as yet, unimportant class on three-stroke- and six-stroke-cycles. As regards design, vertical motors form a big group, horizontal motors a comparatively small one, and inclined motors (excluding those used on bicycles) a still smaller group. Motors may be classified by the number of their cylinders, but this is of no practical advantage, because many makers produce one, two, four, and sometimes three-cylinder motors of identical design, the differences being only the modifications rendered necessary by the coupling of one cylinder to another. The method of working the inlet valves, either atmospherically or mechanically, does not present any essential point of difference between one motor and other; and in fact, some modern cylinder castings can be fitted up with either type of valve. The method of cooling, again, although a most important feature, is not sufficient basis for an intelligent classification, for with but a few exceptions, all high-power petrol motors are cooled by water, which is in turn cooled by the air, and most low-power motors, such, for instance, as are used on cycles, are air-cooled direct. Again, the power developed is no guide, because in some cases all the motors produced by one firm are made to the same general design, the difference being little more than one of dimensions. Under these circumstances, then, there can be but little helpful classification, although all that is possible in this direction has been accomplished here.

Vertical motors will be described first, then horizontal motors, and then two examples of inclined motors. Heavy oil or petroleum motors, cycle motors, two-stroke-cycle motors, special and Diesel motors will then be discussed in the order in which they are here mentioned.

The first to be mentioned is the Gottlieb Daimler motor, which opened the way for all the others, though it is no longer employed in its primitive form. As early as 1885 it was applied to the bicycle, and in 1886 to cars. Until 1889 it was made with one cylinder only, 1½ and 2 h.p., but subsequently two cylinders were adopted for 1-, 2-, and 4-h.p. motors.

The Daimler motor naturally has undergone modification and improvement, and in 1895 was adopted by Panhard and Levassor under the name of the Phœnix-Daimler, but this was abandoned two years or so ago in favour of the Centaure motor. Of course, the German Daimler (Mercedes) and the English Daimler motors are vastly different constructions to the original Daimler motor.

The English Daimler 9-h.p. motor, introduced last year, differed materially from any other two-cylinder motor, but the Daimler company states that the only touring cars it is at present putting on the market have 12-h.p. and 22-h.p. motors respectively, and these are of a more usual design than the 9-h.p. motor referred to. The 12-h.p. motor is shown by Figs. 186 and 187. The fly-wheel A′ is fixed on the rear end of the crank-shaft outside the aluminium crank chamber B, and forms the female portion of the main clutch. The crank chamber is in two parts, divided horizontally about the crank-shaft C, and its projecting feet rest upon the car underframe. The crank chamber provides a central bearing as well as a bearing at each end for the crank shaft C. The two inner crank pins are in line with each other, and are set at 180° from the two outer ones. The big ends of the connecting rod are lubricated from inside. Each pair of cylinders, D, is cast in one piece with their jackets, and is bolted to the crank chamber separately, and independent cover plates E are bolted on the jackets, A. The plug, shown in the head of the combustion chamber, is now dispensed with, the necessary metal wall being now part of the casting. The pipe F leads the circulating water into the jacket between the exhaust valves, and it is led out through the pipe G at the uppermost part of the cover E. Inlet and exhaust valves are shown at H and J, and the igniters screw into the valve chambers at K. I is the exhaust pipe. Each pair of inlet valves is held in place by a single nut and bolt, L, a throttle valve, M, being also fitted

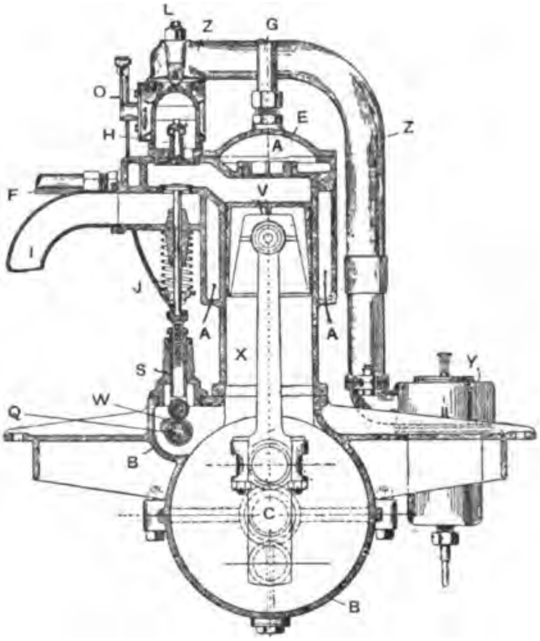


Fig. 186.—Cross Section of English Daimler 12-h.p. Motor.

in the castings N, which hold the valves in place for each pair of cylinders. The levers O, of the two throttle valves M, are connected together by a rod, P, and they are operated by the governor *a*, through levers *b c*. The two-piece cam shaft is coupled together in the centre of the motor. The two cams, W, for each pair of cylinders are made in one piece with a sleeve, and each sleeve is keyed to the cam shaft Q and enclosed in a chamber formed in the crank chamber casting. The cam shaft bearings R have solid brasses, and are carried by circular castings which register into each end of these containing compartments. The cams are lubricated by oil splashed upon them by the revolving cranks. The sliding rods, which are actuated by the cams and which operate the exhaust valves, are carried in guide pieces, S, screwed into the upper metal of the cam chambers. The centrifugal governor *a* is carried by the half-speed spur wheel T, which meshes with the half-sized spur wheel U on the crank shaft. Although not so

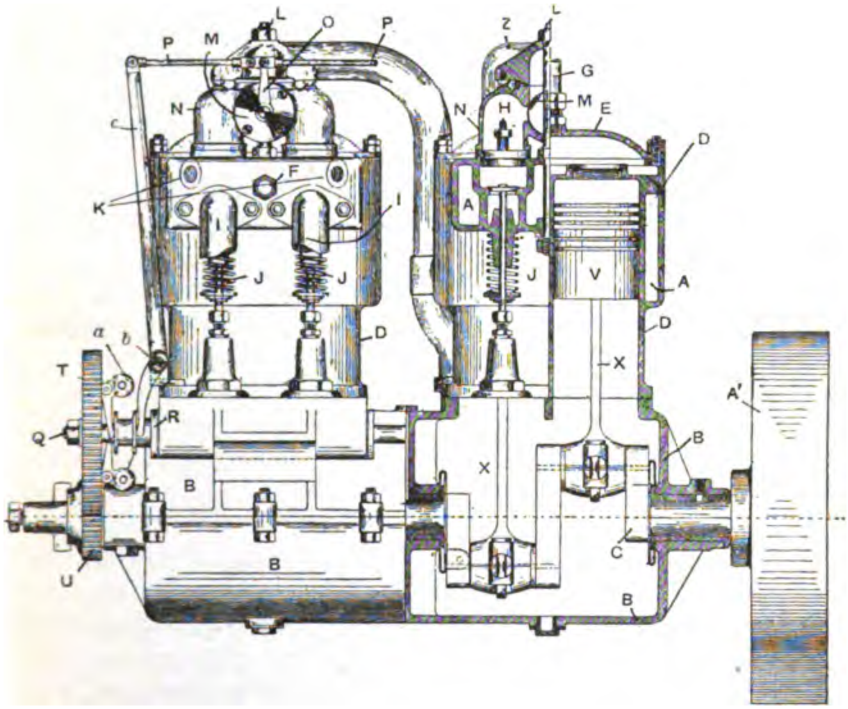


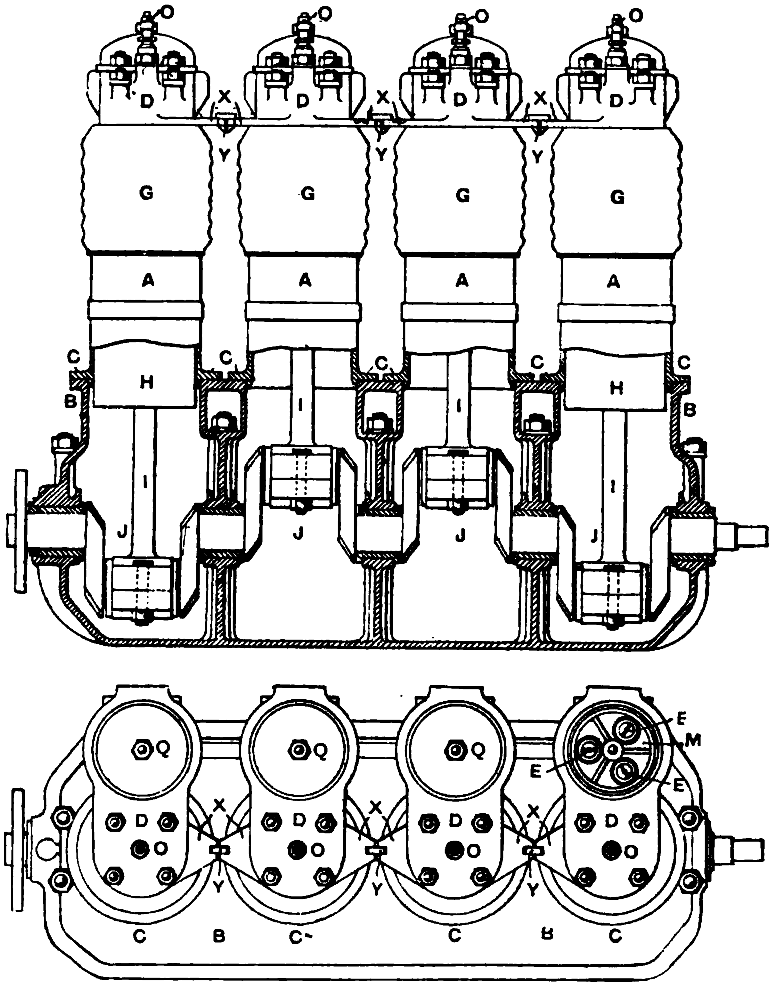
Fig. 187.—Elevation and Sections of Daimler Motor.

shown in Figs. 186 and 187, the pistons V are fitted with two double rings. X shows the piston rods, and Y the carburetter, described on p. 119, with inlet pipe, Z. The normal speed of the motor is 930 revolutions a minute, and the cylinders have a bore of 86 mm. (3·38 in.) with a stroke of 100 mm. (3·93 in.).

The English Daimler 22-h.p. motor also has four cylinders, and in general respects resembles the 12-h.p. above described, the cylinders being of similar design. The governor gear, cam shaft, and valve-operating mechanism are different, however, for the governor regulates the speed of the engine by suspending the action of the exhaust valves consecutively. This motor is also fitted with throttle valves, but they are worked by hand by the driver. The normal speed is 720 revolutions a minute; the cylinders have a bore of 105 mm. (4·13 in.) and the stroke is 130 mm. (5·1 in.). All the English Daimler motors have both tube and electric ignition. A neat combined igniter in the form of a single plug is screwed into the valve chamber of each cylinder. The tubes project into an enclosed metal casing which contains the lamp burners, and these casings are interconnected in such a manner that an extinguished burner will relight itself. As a rule, however, electric ignition alone would be employed, the lamps serving as a valuable stand-by.

Mercedes (German Daimler) 1903 motors, excluding a 90-h.p. racing car motor, are respectively of 18-, 25-, and 60-h.p., and, except in dimensions, these are identical. Each has four vertical cylinders, cast in pairs, and a prominent feature is the encased springs, spiral and slightly coned, of the mechanically—not atmospherically—operated inlet valves arranged centrally on top of the cylinders. The lower power motor has a bore of 110 mm. (4·3 in.), and stroke 140 mm. (5·5 in.), the normal speed being 1,000 revolutions per minute. The bore of the higher powered motor is 140 mm. (5·5 in.), and the piston stroke 150 mm. (5·9 in.). The mechanically operated inlet valves, which are large, are arranged centrally in the cylinder heads, and necessitate special mechanism, the object being to give increased space for the new ignition systems fitted. The degree to which the inlet valves are opened is variable. The hand regulation of the quantity of explosive mixture drawn into the cylinders consists in having the inlet valves opened to a lesser or greater extent, and consequently opened and closed earlier or later during the suction stroke. The movement of the cams on the half-speed shaft is transmitted to the inlet valves through vertical rods which screw into the ends of pivoted levers whose opposite ends press upon the heads of the valve spindles; the vertical rods have small toothed pinions which all are in mesh with a rack. When this rack is moved longitudinally by hand, the rods are caused to rotate and to screw themselves into, or partly out of, the sockets at their heads which engage with the pivoted levers. Thus when the rods are lengthened to their greatest extent, they open the valves and allow them to close up at the usual time in the cycles of operations; but when shortened they allow a variable amount of idle movement between the cams and the valves, and when shortened as much as is possible, the inlet valves remain closed. The exhaust valves are much as usual, and are beneath the yoke, inspection covers being arranged over them ; the exhaust posts from each pair of cylinders are connected together in the cylinder casting itself, the exhaust pipe forking to each pair of cylinders. There are two systems of ignition for separate or combined use. One is the familiar rupture spark given by a magneto machine driven by the motor, but an alteration has been made to facilitate dismounting. The gear-driven magneto is on the same side as the exhaust valves. The low tension sparking plugs are not at the side of the cylinders, but at the front in the place of the inlet valves, which have been moved to the top as already described. So that its working may be quite clear, each plug is placed where the platinum tubes are in those motors employing tube ignition. The sparking rods formerly were pushed, but now they are operated from a special cam shaft, which is driven by gear wheels from the crankshaft, the wires leading to the plugs being connected at their other ends to terminals fixed upon a block of insulating material placed between the cylinder castings. But little information is obtainable about the other ignition system ; however, plugs and a magnet are understood to be employed, and the unbreakable plugs used are "connected by a single wire without coils or accumulators ;" a contact breaker is not necessary, and the current is alternating. This second system is said to have worked well on a 300-h.p. six-cylinder motor made at Cannstatt for the Russian navy.

Panhard and Levassor, as before stated, abandoned the Daimler motor for a new motor—the Centaure—and this itself within the last two years has been modified and improved, the latest type being shown in part elevation and part section by Fig. 188, whilst Fig. 189 is a plan, and Fig. 190 an enlarged vertical section through one of the cylinders. The latest modification was with a view of reducing weight without sacrificing strength, the four cylinders being quite separate and independent, so that, in course of manufacture, each can be turned in the lathe and its weight reduced as desired. As shown in Fig. 190, to the upper part of each cylinder is soldered a water jacket of very thin sheet copper, corrugated so as to give elasticity and allow for expansion. A water-jacketed cap surmounts each cylinder and is attached to it by four bolts tightening a ground joint, whose diameter is less than that of the cylinder. The cap has on it the igniter and contains several inlet valves on one seating screwed into the cap and having its joint made



Figs. 188 and 189.—Elevation, Section, and Plan of "Centaure" Motor.

good by a packing washer held by a cap secured by a central bolt. The cap also contains the exhaust valve worked by a cam on the countershaft, and to support the cap against the push of the cam, it is held to the motor frame by a tie-rod. The crank shaft has a bearing between each pair of its cranks, and also a bearing at each end so that it can be made comparatively light. As illustrated, the motor has four cast steel cylinders (A) side by side, and entirely separate from each other. Each cylinder (A) is fixed to the crank casing B by a flange C. The upper part of the cylinder ends in a narrowed part, on which is fixed cap D, containing the inlet valves E, the exhaust valve F, and the igniting devices O. The jacket G is of thin copper rendered longitudinally elastic by corrugations, this being necessary to allow for expansion. The ends of the jacket are soldered to the cylinder. The piston H and connecting-rod I are as usual. The crank shaft J is journalled in a bearing at each end of each crank, so that it can be made lighter than otherwise would be necessary. The cap D is a casting of curved tubular form K, with water-jacket L, the joint of the cap to the cylinder being ground true and secured by four bolts. There is one exhaust valve, F, but there are three atmospheric inlet valves, E, seating on a disc, M, screwed in an opening, N, provided in the cap. The joint is made good by a packing washer, P, lodged in a circumferential groove and tightened by a cap, Q, held by a central bolt, R. The ignition plug (p. 180) is placed at O. The exhaust valve F is worked by cam S, on the countershaft T, moving a guided rod U.

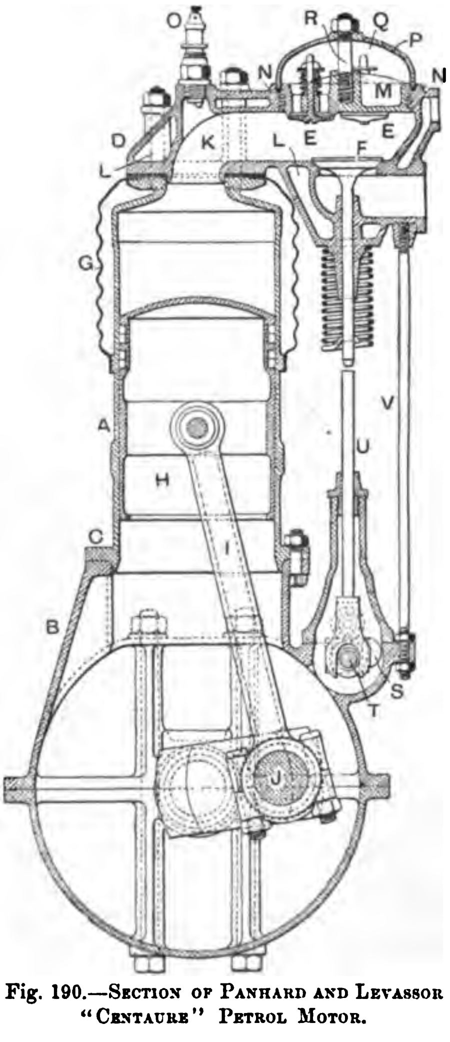


Fig. 190.—Section of Panhard and Levassor "Centaure" Petrol Motor.

The push on the cap exerted on the opening of the exhaust valve is counteracted by a tie-rod, V, one end of which is fixed to the frame B, and the other to the outlet end of the cap. The caps D are connected to one another by lugs, X, cast on them, and by keys, Y. This arrangement has the effect of distributing over several cylinders the lateral stress exerted on a cylinder at the moment of explosion resulting from the oblique pressure on the connecting rod, while in an angular position. The motor uses the new Krebs carburetter (described on pp. 141 to 144), and the jacket water is cooled in a multitubular radiator. In a Centaure four-cylinder motor shown at the Paris Salon, December, 1902, the inlet valves were operated mechanically. The above refers to the type employed on racing cars, such a motor weighing 308 kg. (680 lb.) complete with flywheel developing 70 brake h.p. at a speed of 950 revolutions per minute. The cylinders have been forged from steel, but apparently casting with steel, as in the above, is a later practice. Centaure motors for touring cars adopt the above principles of construction, but are of heavier build.

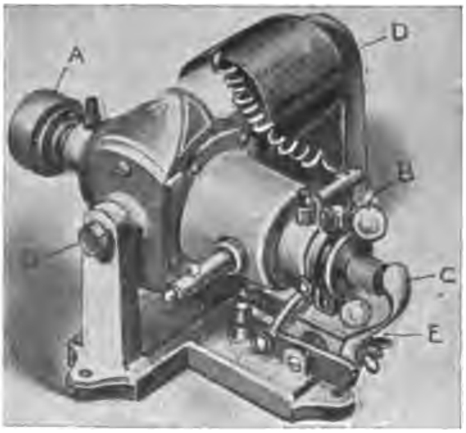


Fig. 191. — Panhard Ignition Dynamo.

Panhard and Levassor are introducing a three-cylinder motor of 8 h.p., of which great things are expected. As in the four-cylinder described above, each cylinder is a separate casting.

The nominal 15-h.p. four-cylinder Centaure motor (braking up to 18 h.p.) employed on the Panhard and Levassor car driven by Jarrott in the September, 1902, Reliability Trials (see p. 792) is also a new type. Each pair of cylinders is cast in one piece with their heads, and the bore is 90 mm. (3·54 in.) and the piston stroke, 134 mm. (5·27 in.). The cam shaft is enclosed in the crank chamber casting, and the motor base is fixed to the car underframe. The commutator is mounted on the front end of the cam shaft, and is connected with an ignition timing lever on the right-hand side of the dash. There is both tube and electric ignition; an autosparker ignition dynamo run by the motor recharges the accumulators and supplies the ignition current direct when the motor speed allows of this. This dynamo is shown by Fig. 191, in which D D are pivots in a stationary casting; at one end the

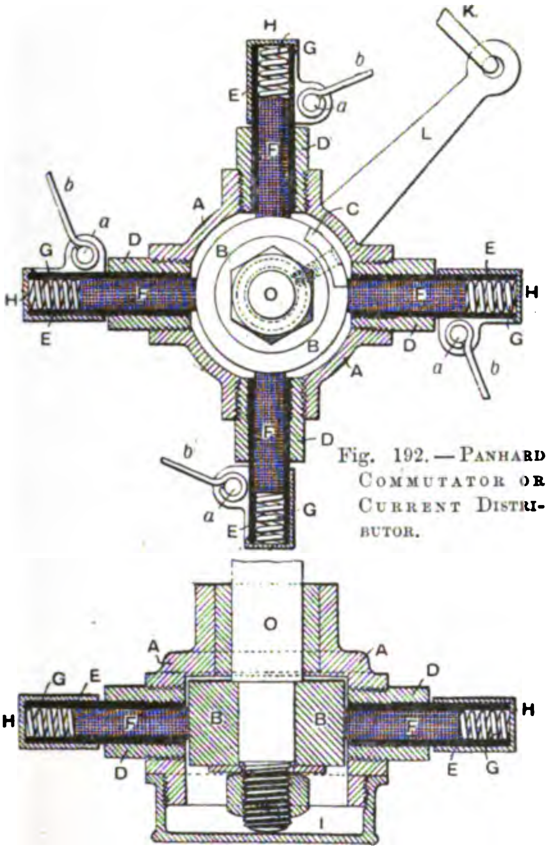


Fig. 192.—Panhard Commutator or Current Distributor.

armature carries a pulley, A, friction-driven by the motor fly-wheel, against which it is spring-pressed. The other end of the armature carries the centrifugal force governor, B, which on the speed increasing forces a sleeve outwards against a pivoted lever, C. This lever is so connected that it tips up that end of the dynamo proper, thus breaking the friction contact between the pulley and the motor fly-wheel. The dynamo speed is thus limited, its precise speed depending on the tension of the spring, which is altered by means of the thumb nut E.

The Panhard and Levassor firm has a new method of distributing or directing the current successively to the induction coils of a multicylinder motor. The apparatus is shown in horizontal and vertical sections by Fig. 192. A shaft which is driven by the motor has a boss of insulating material revolving within a stationary sleeve having projecting from it as many hollow arms as there are cylinders in the motor. Each arm contains a wire gauze brush enclosed in a non-conducting tube. On the periphery of the insulating boss is fixed a piece of metal electrically connected to the shaft which is in the electric circuit. As the shaft revolves this metal piece rubs over the brushes in succession, thus closing the circuits of the several induction coils one after the other. By turning the sleeve partly round the moment of ignition may be advanced or retarded. The apparatus has a cylindrical body, A, shown by Fig. 192, fitted with moderate friction on the shaft O; fixed on this shaft also is the distributing cam B, made of insulating material and having a metal piece, C, screwed to the shaft. The body, A, has as many projecting bosses as there are cylinders of the motor, and on these bosses are fixed brush holders, each consisting of an insulating cylinder, D, screwed in the boss, a metal tube, E, passing through the cylinder, D, a cylindrical brush, F, consisting of a roll of fine wire gauze, a helical spring, G, pressing on the brush, F, and a cap, H, split on one side and clamped by a screw, *a*, which at the same time fixes the conducting wire *b*. The apparatus operates as follows: The shaft O as it revolves brings the piece C to each of the brushes in succession, thus connecting the shaft O to the conductor *b*, leading from that brush to the coil. The position of the body A upon the shaft O can be varied by means of the handle K and lever L, attached to A, the period of ignition in the cylinders being thus regulated by adjusting the points of the revolution where the primary current is transmitted. The front of the body A has a cap, I, which protects the brushes and cam from dust and rain.

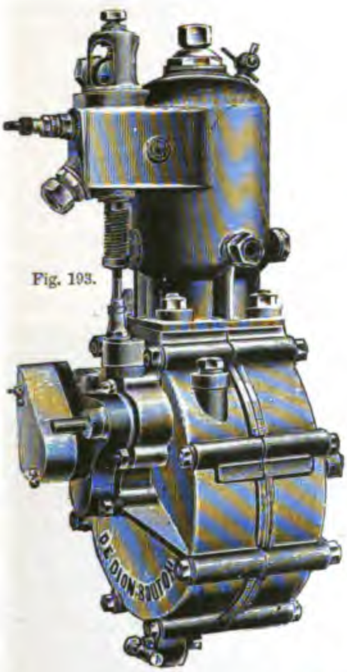


Fig. 193.

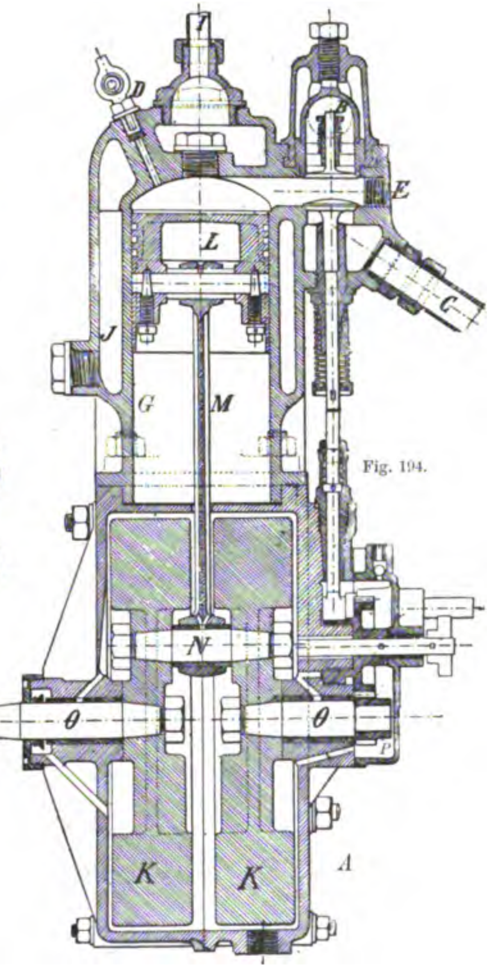


Fig. 194.

Fig. 193.—De Dion-Bouton One-cylinder Motor.

Fig. 194.—Section of de Dion-Bouton Motor.

The de Dion-Bouton 4½ brake h.p. one-cylinder motor is shown by Figs. 193 to 196. Fig. 193 is a general view, Fig. 194 a cross section, Fig. 195 shows the igniter, and Fig. 196 the motor, carburetter, etc., and their connections. Referring to Fig. 194, A is the aluminium crank-case made in halves jointed in an oil-tight manner, and to it is bolted the cast-iron cylinder G with water-jacket J. The inlet valve B is spring-controlled, the exhaust valve C also being spring-controlled and opened at definite intervals by a cam; this cam with its gear is actuated by pinion P on the motor shaft. The piston L is of cast iron and M is the connecting rod, N being the crank fixed to the fly-wheels K, and serving as a bearing for the lower end of the connecting rod. The motor shafts O communicate their power by means of pinions. The sparking plug is screwed into the threaded hole E, and the compression tap into D. The water is removed from the jacket at I. With regard to the contact breaker, Fig. 195, a is the insulating plate or base upon which are mounted the two supports or standards b and v. The former carries the trembler t, and through v passes the platinum-tipped regulating screw d, whose end makes contact with a little platinum boss on the trembler. At the lower end of the trembler spring is riveted a steel shoe which fits into a notch in the motor-operated cam c. As the cam is revolved, the trembler

Fig. 196.

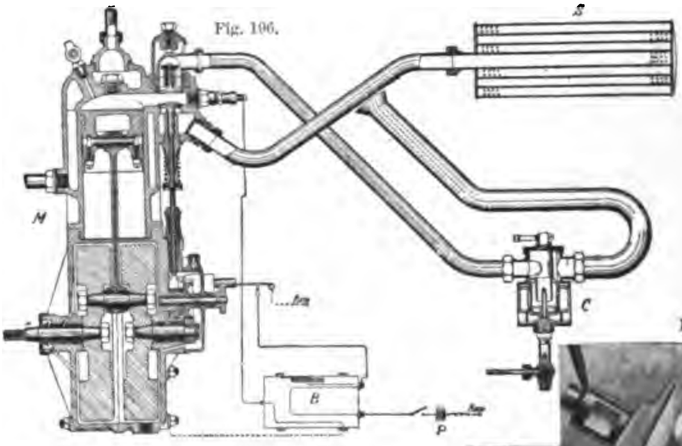
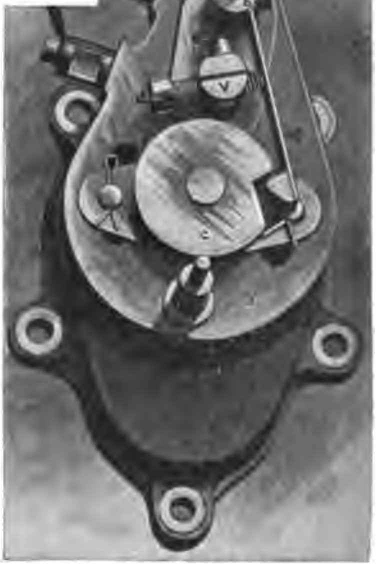


Fig. 195. — De Dion-Bouton Contact Breaker, etc.

Fig. 196. — De Dion-Bouton Motor System.

Fig. 195.



shoe falls into the notch of the cam c, and screw d and trembler t become in contact. As the cam lifts the shoe out of the notch, the circuit is interrupted. The moment of contact and consequently of ignition is varied by moving the vibrator around the cam shaft. In the scheme illustrated by Fig. 196, B is the coil; C, carburetter; M, motor; P, battery, and S, exhaust silencer.

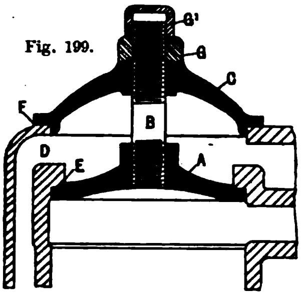
The above may be regarded as the de Dion-Bouton standard type as regards the details of construction, but some other motors, of course, are of higher power. The Populaire voiturette has attracted much attention, and this has a 6-h.p. motor, single-cylinder, fixed in front to two inner longitudinal members of the tubular frame. It does not differ much from the above, having no external flywheel or clutch, the crank shaft being connected to the first-motion shaft of the change-speed gear by means of a longitudinal shaft having universal joints (for further particulars of the transmission, see p. 400). The motor drives through a helical spring a pump which is fixed to the front of the tubular frame, and which circulates the cooling water through a radiator; the shafts of motor and pump are in line, and a very flexible drive results.

The de Dion-Bouton 10 h.p. motor (Fig. 197) has two cylinders, cast together in one piece with their jackets. The atmospheric inlet valves are held in place above the exhaust valves by yoke Y and a nut, the induction pipe fittings for each valve being separate. The oil pump P is a novel feature; it circulates the lubricating oil to the crank chamber, and is driven through vertical shaft S by spiral gearing from the cam shaft; it takes oil from the bottom of the crank chamber and returns it to the oil supply tank T, fixed to the cylinder casing. The cam shaft is mounted in ring-lubrication bearings. This motor has a special commutator and contact-breaker, shown by Fig. 198. The various parts are mounted on a metal base plate, from which are insulated the contact pillars A and B and their respective terminals C and D. The device is mounted about the cam shaft, but can be removed without interfering with the cams, owing to the presence of spring plungers, E, which can be drawn outwards against the action of enclosed springs. Two cams (F and G) are fixed beside one another to the shaft, their projections being at an angle of 90°; they act upon hardened steel pins, fixed to the ends of a forked piece pivoted at H, to which a contact-making spring, J, is attached. Cam F causes the contact spring to make circuit with the fixed contact C, and cam G is scooped out to allow the pin, which it operates, to move inwards for this purpose. This gives quick make and break. Fly nuts on pillars K hold in place a light cover, which fits over the moving parts. L shows attachment to timing lever.

A new method of forming cylinder heads, patented by de Dion-Bouton, has the object of affording means to vary the compression space in each cylinder, so that a little experimenting shows exactly the space that gives the best results; it also gives easy access to each cylinder. Instead of casting the cylinder and water jacket in one as hitherto, both combustion chamber and jacket have solid concave ends or lids, A and C, Fig. 199; A is held close to the underside of the flange E at the end of the cylinder, whilst C bears on an outer flange (F) on the water jacket wall, and closes the water space above the combustion chamber. The screwed stud B connects the two caps, which are tightened upon their flanges by screwing down nut G, which has a lock-nut G^1. This method may answer if the joints of the caps can be made perfectly gas and water tight.

Simplicity is the feature of the Thornycroft petrol motors just introduced; these are of 10 h.p. and 20 h.p., and are of similar design, which seems to embody a few points that are new and many that modern practice has approved. The 10-h.p. motor has two cylinders, and the 20-h.p. motor has four cylinders, as illustrated in Figs. 689 and 690, p. 641. The bore is 101·6 mm. (4 in.) and the piston stroke 111 mm. (4·375 in.), and the one-piece steel crank shaft has its cranks set opposite each other, and is without any central bearing. The pistons are long and have four cast-iron rings. The aluminium crank chamber has a bottom cover that is removable without affecting the crank shaft, whose bearings are in the upper part of the chamber. The crank shaft prolonged carries the governor and the spur-wheel that operates the pumps, and terminates in a spring clutch connection for the starting handle. At the other end the shaft carries the customary fly-wheel clutch. The inlet valves are not mechanically worked, and are placed vertically above the exhaust valves, the ignition plugs being screwed in midway between the two. The design admits of mechanically operated valves, whose advantages, by the way, the Thornycroft company considers to be a matter of conjecture. In common with the James and Brown 1903 motor, and the Charron, Giradot, and Voigt motor, the inlet valve seatings are held down by a single nut and stud, the latter bearing on a cross-piece whose ends are pressed down upon the two branches of a hinged and breeched aluminium induction pipe; the ends of these branches have narrow collars bearing upon the inlet valve seatings. The cam shaft gear is as usual, but between the cam and the end of the exhaust valve stem, which is very long and of bronze, is a hard steel roller 22·2 mm. (·875 in.) in diameter to diminish friction and to prevent side-thrust on the valve stem; the roller has the advantage over a ball in this position of providing a line-contact with the driving cam. A centrifugal force governor on the crank shaft throttles the intake; and the throttle valve is

Fig. 199.



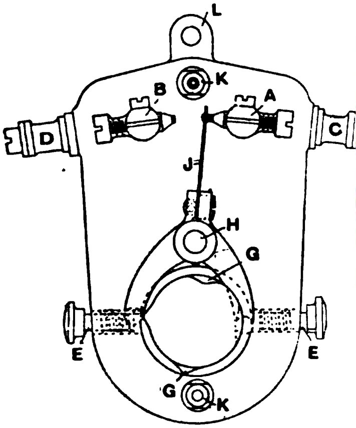


Fig. 198.

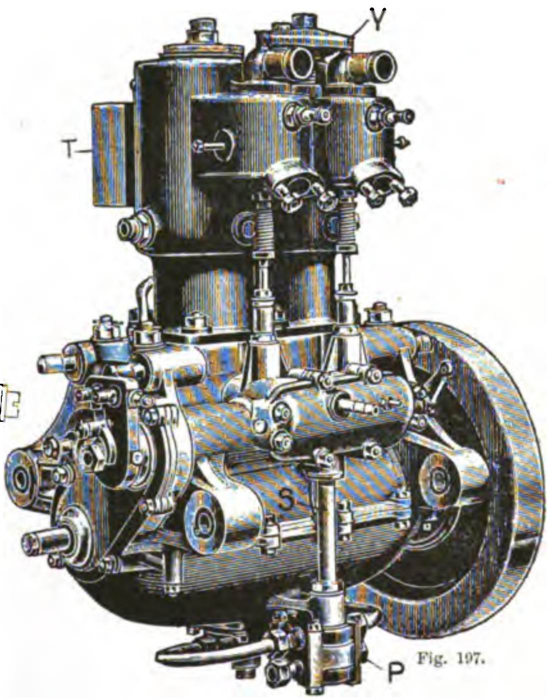


Fig. 197.

Figs. 197 and 198.—De Dion-Bouton Two-cylinder Motor and Contact Breaker.
Fig. 199.—De Dion-Bouton New Cylinder Head.

so arranged that when the speed increases an auxiliary air supply is opened automatically, thus keeping the proportions of the charge approximately constant. There is the usual accelerator to cut out the governor. For the high-tension ignition either accumulators or a dynamo can be used; in the latter case, the motor at starting takes current from the accumulators and, after a certain speed has been reached, from the dynamo; for this purpose there is a special switch, invented, it is believed, by Sir John Thornycroft.

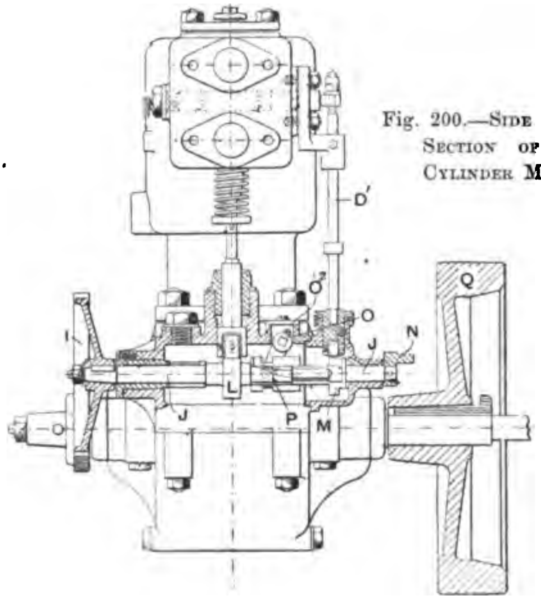
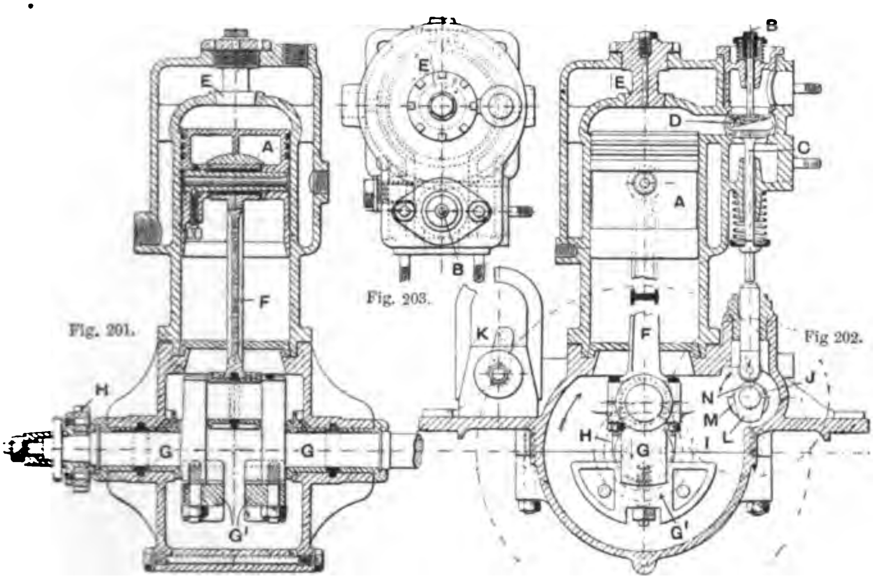


Fig. 200.—Side Elevation and Section of Simms One-Cylinder Motor.

A centrifugal force governor on the dynamo spindle limits the dynamo speed. Cooling is by water, and a multitubular radiator can be used if desired, there being provision on the motor shaft for driving a fan.

The Simms single-cylinder motor has a water-jacketed cylinder cast in one piece, and cooling is very effective. The cylinder is of 110 mm. (4·33 in.) bore and 100 mm. (3·93 in.) piston stroke, the working compression being 6·3 kg. per cm.^{2} (90 lb. per sq. in.) and the power 6 brake h.p. at 1,000 revolutions, and 7 brake h.p. at 1,200 revolutions per minute. With a 70 kg. (154 lb.) fly-wheel the motor weighs 152 kg. (334·4 lb.), this including carburetter, etc. The height over all is 57·17 cm. (22·5 in.), the width over brackets is

45·7 cm. (18 in.), and the length from end of crank shaft to outside of fly-wheel is 50·8 cm. (20 in.). The motor is shown in side elevation and section by Fig. 200, in longitudinal section through cylinder and crank shaft by Fig. 201, and in cross section through cylinder and valves by Fig. 202; a plan of the cylinder head is given by Fig. 203. The cam shaft operates the exhaust valve, the low tension ignition plug, and the magneto machine, and is carried across the outside of the crank chamber, and runs in an oil bath for the greater part of its length; it is driven by a fibre pinion on the crank shaft gearing with a phosphor-bronze wheel. A timing lever allows the ignition cam gear to be adjusted relatively to its shaft on the Simms patent system; and variations corresponding to motor speeds between 200 and 1,500 revolutions per minute thus can be made. Counterweights opposite the crank-pin on the main shaft are intended to balance the revolving parts; special lubrication channels and passage in the crank chamber ensure automatic lubrication of the various bearing and thrust surfaces. The carburetter is of the float-feed type, and is automatic in its action. The letters on Figs. 200 to 203 have the following references:—A, piston; B, inlet valve; C, exhaust



Figs. 201 and 202.—Sections of Simms One-cylinder Motor. Fig. 203.—Cylinder Head of Simms Motor.

valve; D, low tension igniter; D^1, rod working the igniter; E, inspection plug in head of cylinder; F, connecting rod; G, crank shaft with special lubrication of bearings; G^1, counter-weights to balance connecting rod and piston; H, pinion on motor shaft; I, spur wheel on cam shaft; J, cam shaft passing through crank chamber; K, magneto-generator operated by pin N on cam shaft; L, exhaust cam; M, plug which actuates igniter; N, crank pin working magneto through connecting rods (not shown); O, rocking shafts regulating time of ignition; O^2, inspection cover; P, fork for sliding cam M, and crank pin N; Q, fly-wheel.

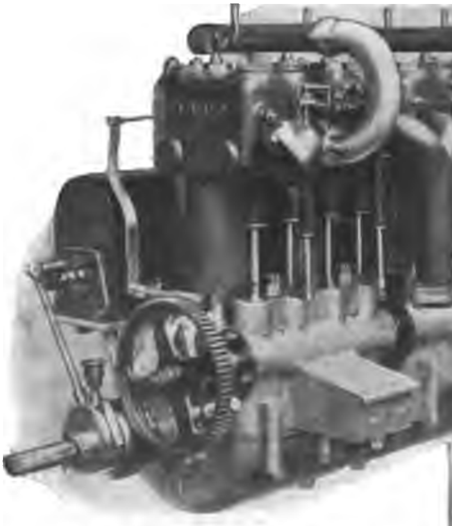


Fig. 204.—Simms Four-Cylinder 20—24 h.p. Motor.

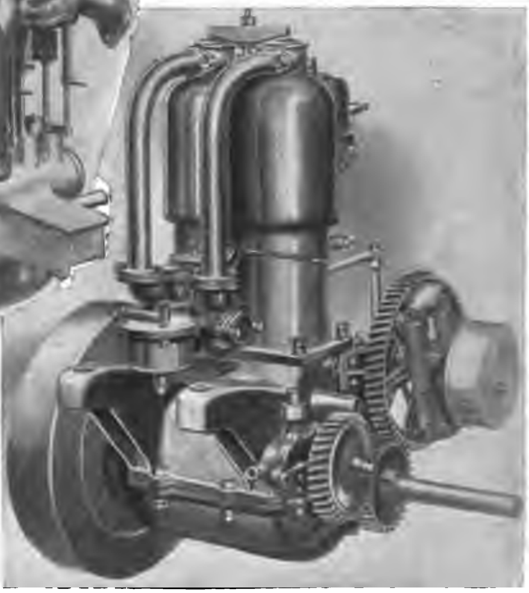


Fig. 205.—Brush Two-Cylinder Motor.

Other types of Simms car motors have the same kind of details, but differ in being twin-cylinder or four-cylinder and of higher power, whilst there is a small 2-h.p. air-cooled bicycle motor embodying the same principles of construction. The 8-h.p. type has a normal speed of 1,000 revolutions per minute, and at a higher speed can give 11 h.p. Each of the two cylinders has its own exhaust pipe. The 12-h.p. two-cylinder motor runs normally at 1,200 revolutions per minute, but at 1,500 revolutions per minute it

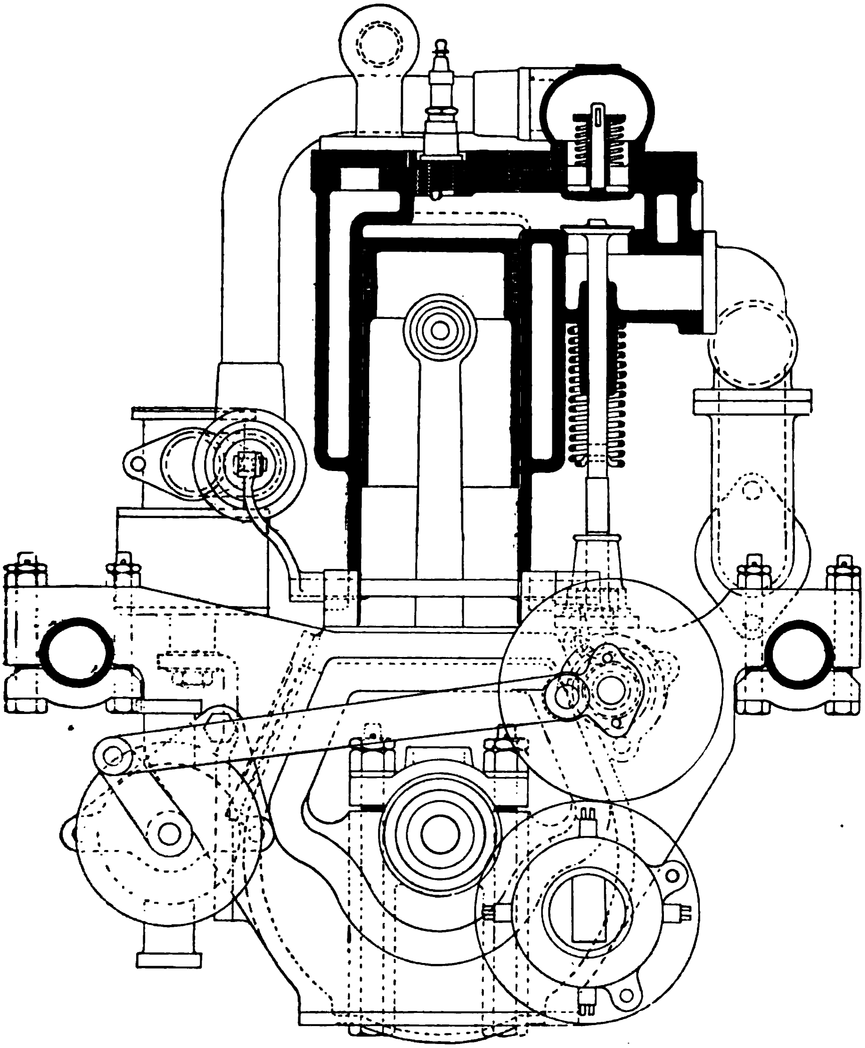


Fig. 206.—Section of Humber 12 h.p. Motor.

gives 15 h.p. The bore of its cylinders is 110 mm. (4·33 in.), and the piston stroke 100 mm. (3·93 in.). Simms four-cylinder motors (see Fig. 204) have mechanically operated inlet and exhaust valves,

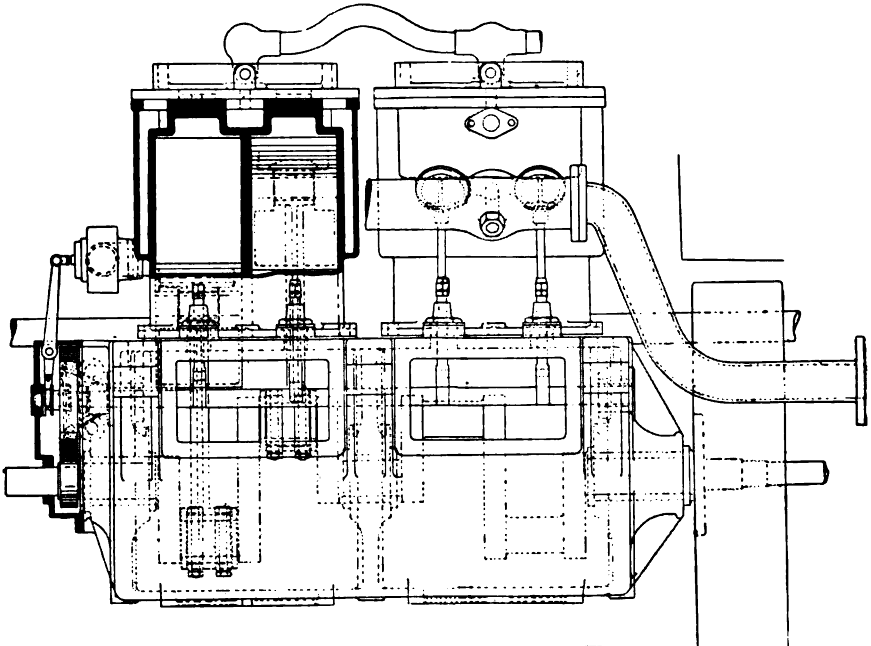


Fig. 207

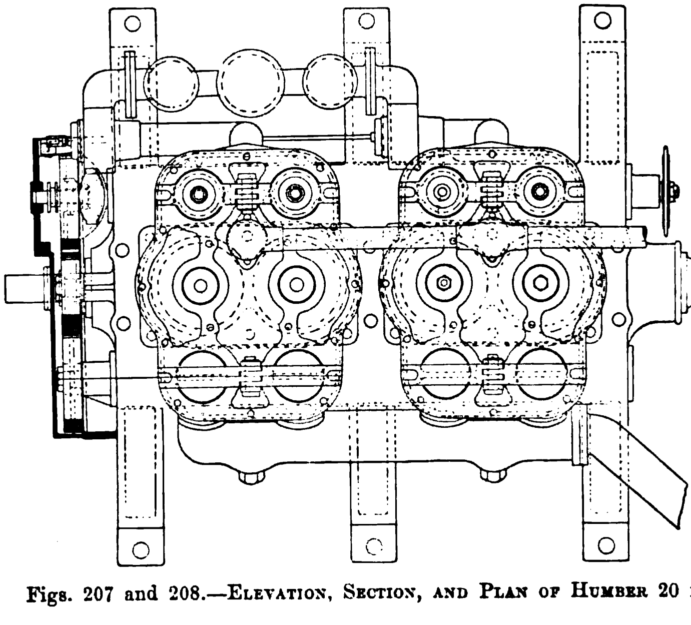


Fig. 208.

Figs. 207 and 208.—Elevation, Section, and Plan of Humber 20 h.p. Motor.

and are respectively of 20 to 24 h.p. and 30 to 35 h.p. The compression in both is 6·3 kg. per cm.^{2} (90 lb. per sq. in.), and bore and stroke are 95 mm. and 110 mm. (3·74 in. and 4·3 in.) and 110 mm., the normal speed being 1,200 revolutions per minute.

The new Brush motors of 8 h.p., 12 h.p. and 16 h.p. are of the Daimler type, and brake up to 11 h.p., 14 h.p. and 23 h.p. respectively. The 8-h.p. one (Fig. 205, p. 226) is two-cylinder, the others four-cylinder, but they are of precisely the same design. The cylinders are cast in pairs with their jackets and heads, and the atmospheric inlet valves are in the centre of the cylinders on top. The exhaust valves and their gear are much as usual, and inspection covers are above the valves. The cylinders are bolted to the top of the crank chamber, which in the four-cylinder motor is in four pieces. The upper portion between the main bearings and the cylinder is in one piece, and there is a separate base below each pair of crank pins. The crank shaft is forged and turned from nickel steel. The cam shaft is enclosed, and the governor is contained inside the helical toothed spur-wheel driven by a corresponding wheel on the forward end of the crank shaft.

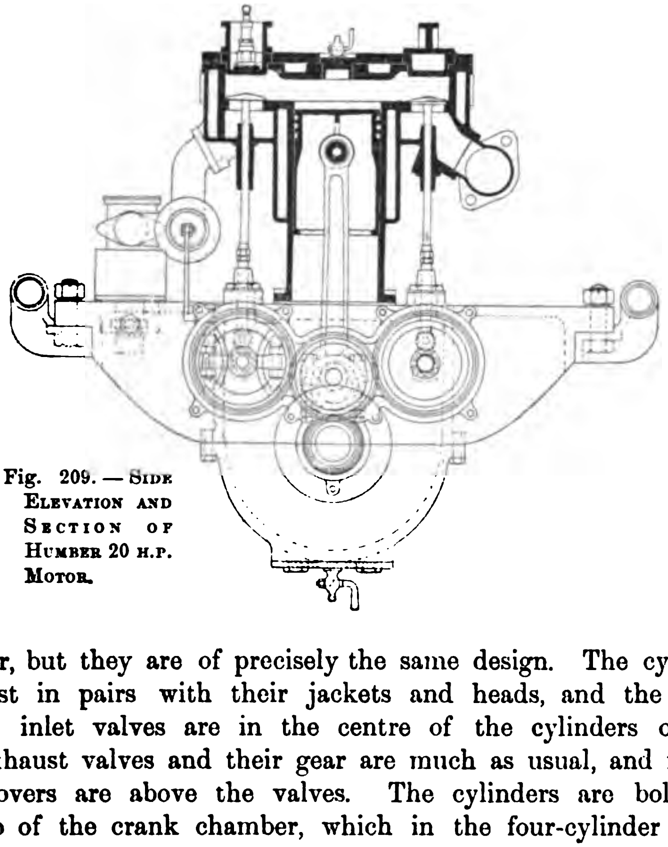


Fig. 209. — **Side Elevation and Section of Humber 20 h.p. Motor.**

The commutator, illustrated as being on the end of the cam shaft, is fixed on the car dashboard when the motor is in place, and it is then chain-driven. The circulating pump is of the gear-wheel type, and is driven by the spur-wheel that also drives the half-speed shaft. The usual governor acts on the throttle, and there is an accelerator. Generally, ignition is by means of the Brush-Dawson magneto, but batteries or tube ignition may be used instead (*see* p. 600). The 8-h.p. and 16-h.p. motors have a bore of 100 mm. (3·93 in.) and a piston stroke of 140 mm. (5·5 in.), and the 12-h.p motor a bore of 85 mm. (3·34 in.) and a piston stroke of 118 mm. (4·6 in.). The long stroke in relation to the bore will be noted.

The two principal types of Humber motors (excluding the cycle motor described on p. 282) are nominally of 12 and 20 h.p. respectively; each has four vertical cylinders. The smaller motor shown in section by Fig. 206, p. 227, braking up to 14 h.p., has a bore of 95·2 mm. (3·75 in.), a stroke of 101·6 mm. (4 in.), and the normal speed is 900 revolutions per minute. The inlet valves are operated atmospherically. The Longuemare carburetter is gravity fed, and throttling is both hand and automatic; ignition is, of course, electric. The cylinders are cast in pairs with a large waterway covered by an aluminium plate. The larger motor (Figs. 207 to 209) brakes up to 25 h.p., and whilst greatly resembling the other it has one or two more modern features. The cylinders are of the same design, but their bore is 108 mm. (4·25 in.) and stroke 146 mm. (5·75 in.). The speed is 900 revolutions per minute, and both inlet and exhaust values are operated mechanically. Carburetter, throttling, ignition, etc., are as in the smaller motor. In both cases a semi-rotary circulating pump is directly driven off the motor shaft. A contact breaker on the dash is chain-driven from the cam shaft. Fig. 207 is a part front elevation and part section, Fig. 208 a plan, and Fig. 209 a part end elevation and part cross section.

The Weller motor is a new English motor, one type of which has three cylinders, the two outer cranks being in line, and the remaining one opposite them, Whatever be the number of cylinders, each crank is in a separate chamber, the chambers providing the crank shaft bearings, and being bolted together by three steel rods. The inlet valves are opened normally by helical springs, which are stronger than the ordinary springs, holding the valves on their seats. Cams allow the valves to close, and the motor is regulated by limiting the extent to which they open.

In the Soames two-cylinder vertical motor governing is by hand. To vary the volume of mixture admitted the tension of a spring is regulated, this tending to close a valve through which the mixture passes to the inlet valves; alongside this regulating valve is a valve through which cold air passes to the cylinders when the supply of mixture is quite cut off.

The method adopted for throttling the Soames motor by hand and for admitting cold air to the cylinders when no explosive mixture is required, such as when running down a steep hill, is indicated in Fig. 210. The Longuemare carburetter is connected by the pipes A and B with the inlet valves. A leads into a valve box, C, and the passage through it to the pipe B is controlled by a valve, D, whose rod is connected through spring E by the cord F, and the screw G with a pivoted drum, H, to which a lever, J, is fixed. The drum H is also connected by the cord F to another spring, K, which is attached to the spindle of valve L. Springs E and K can normally hold both the valves down on their seats against the motor suction. The valve D controls the passage of the explosive mixture, as already stated, and the valve L permits air to be drawn in past it when the spring K allows it to. The lever J is connected with a regulating lever, which lies parallel with the steering pillar in front of the driver, and by turning this hand lever, the drum H can be rotated about its axis, and either the valve D or the valve L can be allowed to open more or less freely. In this manner the explosive mixture can be throttled to the desired extent, a braking effect can be obtained, or the cylinders can be cooled by the admission of pure air.

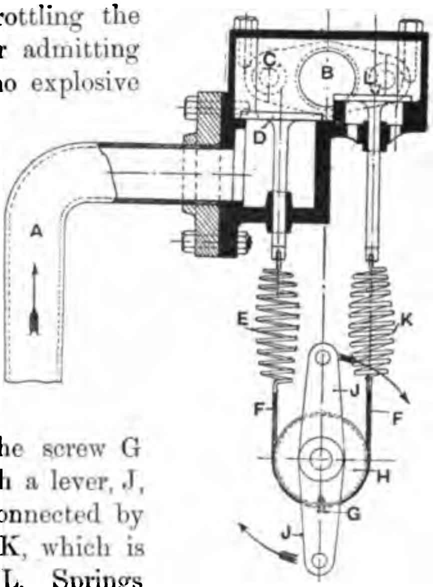
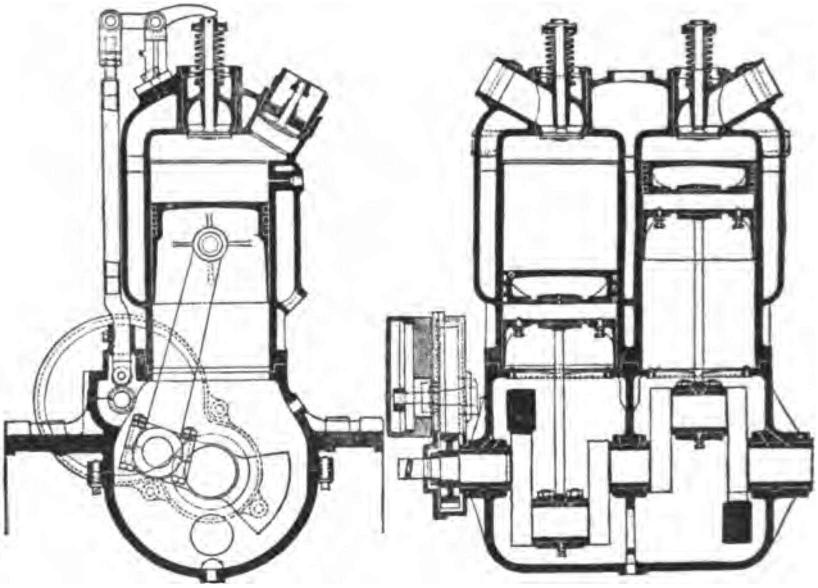


Fig. 210.—Soames Motor Regulation System.

The unusual positions of the valves form a feature of the Primus two-cylinder motor (Figs. 211 and 212). The exhaust valves are central, and are operated by cam, rod, and lever, as clearly illustrated. The atmospheric inlet valves are at the side.

The Milnes "Voiturette" motor has two vertical cylinders cast in one piece, and the few reference letters in the following description have regard to Figs. 654 and 655 (p. 609), which show the motor and transmission gear. The cylinder bore is 90 mm. (8·54 in.) and the stroke is 120 mm. (4·72 in.). The mechanically operated inlet and exhaust valves for each cylinder of motor, B, are in a common valve chamber, and their stems project downwards: low tension ignition plugs fit into the sides of these chambers, and above the valves are inspection plates, held down by a yoke piece and nut. The water jacket passes round the valve chamber, the water entering at each end. The inlet and exhaust valves now are on the right side, but in later models will probably be on the left. The circulating pump and the fan are driven by spur wheels, which mesh with a large wheel on the cam shaft: this shaft is worked as usual. The large wheel mentioned carries a centrifugal force governor (this can be cut out by an accelerator) whose sliding sleeve is connected with the throttle



Figs. 211 and 212.—Sections of Primus Two-cylinder Motor.

valve. An oscillating magneto on the left, driven by an eccentric on the crank shaft, will in later models be replaced by a rotary magneto, gear-driven from the half-speed shaft. Lubrication has received great attention; for instance, the cam chamber is oiled from a separate lubricator, the entrance to which is controlled by a small ball valve; for filling, the spout of the oilcan depresses the ball against the action of a weak spring. For the solid forged crank shaft there are very long bearings, partly formed by the lower and bolted-on portion of the crank chamber. A big flywheel, C, is fitted on the crank shaft. The radiator and tank in one, P, is of the multitubular type.

The Milnes (or Milnes-Daimler) 20-h.p. four-cylinder motor has mechanically operated inlet valves, and low tension magneto ignition. Each plug can be disconnected electrically instantly by means of a switch arm which is mounted on an insulated rod passing along the top of the cylinders, and which engages with spring clips on each plug. The insulated wire from the magneto is connected to the end of the insulated rod, and the four switch arms are normally held in place and make contact with their respective plugs. Ignition is not variable except in so far as the greater the motor speed the greater the quantity of current generated by the magneto, and therefore the more intense the spark in the combustion chamber. The cam shafts, one each side, are not enclosed, and are driven by a brass spur-wheel on the forward end of the crank shaft. The Simms-Bosch magneto has a revolving cast-iron shield between armature and field.

Mors modern vertical motors are made in the following sizes: 6, 8, 11, 12, 15, 18, 22, and 30 h.p., all being vertical, and all having four cylinders except the first mentioned, which has two; the motors chiefly used are those of 11 and 18 h.p. Fig. 213 shows the two right-hand cylinders, the other two being similar. This motor typifies the latest construction of automobile motors, in which the inlet valves are operated mechanically. Each cylinder is a separate casting with its water-jacketed head and valve chambers. The jackets for the cylinder walls, however, are of aluminium and are cast in pairs, but when fixed with studs to the cylinders there is communication between all four of them. The cylinders are forced down into place, and the jackets hold them to the crank chamber. The inlet valves are on the opposite side to the exhaust valves, and there are inspection plugs for all the valves. The ignition plugs fit into the tops of the cylinders, and they are served by separate knife switches. Ignition is low tension, the current coming from a gear-driven magneto attached to the crank chamber on the opposite side to that illustrated in Fig .213. The ignition plugs form the insulated spark points with which an uninsulated rocking arm makes and breaks contact. The other portion of the ignition device passes through the side of the combustion chamber near the inlet valve chamber, the rocking arm itself being kept cool by the incoming explosive mixture. The igniters are operated by cams on the shaft that carries the inlet valve cams, Fig. 213 showing the vertical rods passing up to the igniters. On a motor exhibited at the Paris Salon, in 1902, the moment of ignition was varied by a small shaft parallel with the cam shaft just mentioned; this small shaft was controlled by a hand lever above the steering wheel, the connection being through a hollow steering pillar. There are two cam shafts on each side of the motor, the cams being enclosed in casings bolted on. These are driven by spur wheels, which mesh with a common wheel on the crank shaft, and to make the larger wheels run silently they are built up of fibre and brass, as illustrated, in a manner adopted on some other modern motors. These built-up wheels on the Mors motor are three-ply, the brass being between the fibre, as shown to the right in Fig. 213; in motors of some other makes brass is outside and fibre inside. The governor is fitted into the large spur wheel on the inlet cam shaft, and operates a throttle valve on the carburetter outlet. The new Mors carburetter is described on p. 126; only one is used for all the four cylinders, its pipe branching to each pair and then again to each cylinder. The body of the crank chamber and the projecting feet are cast in one piece, and the end barings are solid bushes supported in disc castings, which form the front and rear of the chamber. The crank shaft drives a fan placed immediately behind the multitubular radiator. The starting handle is connected with the crank shaft through spur wheels, there being between the two a simple clutch, resembling a bicycle "free wheel" clutch, to facilitate starting, and to avoid injury to a person's wrist should the charge ignite prematurely.

The Mors system of volume throttling is shown by Fig. 214. The throttle valves A on the induction pipes are worked by levers B, on the valve shaft C, which operate under the action of the governor D. Of the two springs E and F, the former is the stronger, and tends to open the valves. With these springs, the valve action is more sensitive than when the governor alone is used. The throttle, worked by hand, or by the governor, or by both, reduces the volume of the charge admitted and thus slows down the motor.

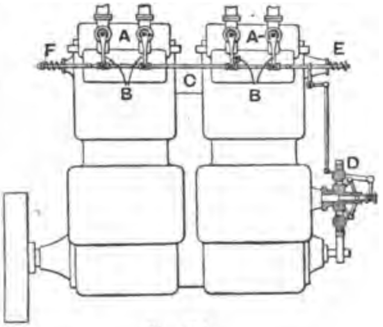


Fig. 214.

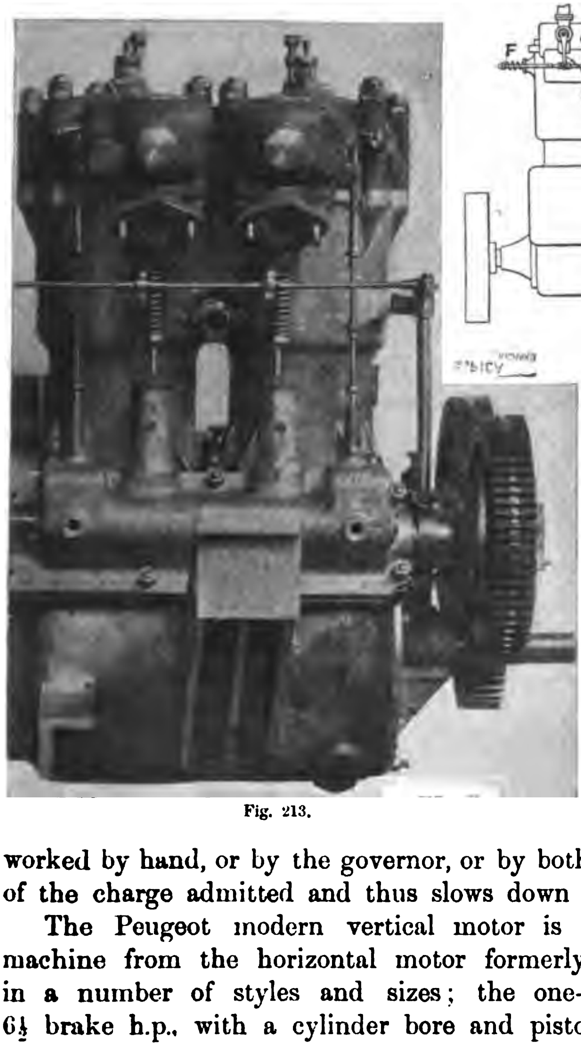


Fig. 213.

Fig. 213.—Half Elevation of Mors Four-cylinder Motor.

Fig. 214.—System of Governing Mors Four-cylinder Motor.

The Peugeot modern vertical motor is an entirely different machine from the horizontal motor formerly used. It is made in a number of styles and sizes; the one-cylinder motor is of 6½ brake h.p., with a cylinder bore and piston stroke of 100 mm. (3·93 in.), and its speed is 1,000 revolutions per minute; this is the motor used on the Baby Peugeot car which has made such good performances. The two-cylinder motor is of 10 h.p. (as was also an older type of four-cylinder motor of 94 mm. (3·7 in.) bore and stroke, and the new four-cylinder motors are of 12 and 18 h.p. respectively; these have mechanically operated inlet and exhaust valves, the former to the right of the combustion chambers and the latter to the left, and a separate exhaust pipe connects each cylinder to the exhaust box alongside the motor. The two cam shafts are driven by enclosed gear wheels, and a circulating pump is gear-driven in front of the crank chamber. When low and high tension ignition is fitted, the low-tension igniters are operated by cams on same shaft as those that operate the inlet valves, the current being generated by a gear-driven magnet, fixed to the right-hand side of the crank chamber. This cam shaft carries a centrifugal governor in front, whilst at its other end it chain-drives a commutator and belt-drives a lubricator. The governor regulates the motor speed by means of a throttle on the intake. Thus the Peugeot motor does not very greatly differ from some other first-class modern motors, but the means of actuating the inlet valves is interesting.

One type of modern Benz car has a horizontal motor, but in the latest twin-cylinder type the cylinders are vertical and form a single casting. The 10 to 12 h.p. motor has a bore of 101·6 mm. (4 in.) and a stroke of 111 mm. (4·375 in.), and the speed varies between 300 and 1,200 revolutions a minute. The induction valve is atmospheric. To make the valve chambers accessible, the covers are held down in their seatings by the inlet pipe fittings, secured by a yoke piece and nut. The throttle valve is regulated by a centrifugal governor, and by a small hand-lever near the steering-wheel. The general arrangement of the motor is shown in Fig. 215; the enclosing castings are of aluminium. A single exhaust pipe leads to the exhaust box from a branched fitting communicating with the two cylinders. Ignition is on the low-tension system, the igniter fitting into the side of the valve chamber between the inlet and exhaust, the current being generated by a gear-driven magneto. The spray carburetter is of the Richard-Benz type (*see* p. 136), as is also the new radiator for cooling the water. The circulating pump in front is driven by spur gearing; a fork projects for its spindle, as shown, and its prongs engage in slots in the governor spur wheel, and thus it is driven on the lathe-carrier principle. A hand force-pump on the lubricator box feeds oil to the crank chamber.

The Chenard and Walcker twin-cylinder motor, shown in Fig. 216, has an aluminium crank chamber, whose four feet are bolted to the underframe. The two cylinders are cast in one piece with their jackets, and the valve chambers are formed on each side, inlet valves on the right, exhaust valves on the left. The mechanically operated inlet and exhaust valves are interchangeable and are normally held on their seats by strong springs. The two cam shafts lie inside the crank chamber on either side, and are driven by spur-wheels through an intermediate wheel from a half-sized gear wheel on the crank-shaft. The central part of the crank chamber is made in one piece, and is fitted with flat-end castings, which carry the crank shaft

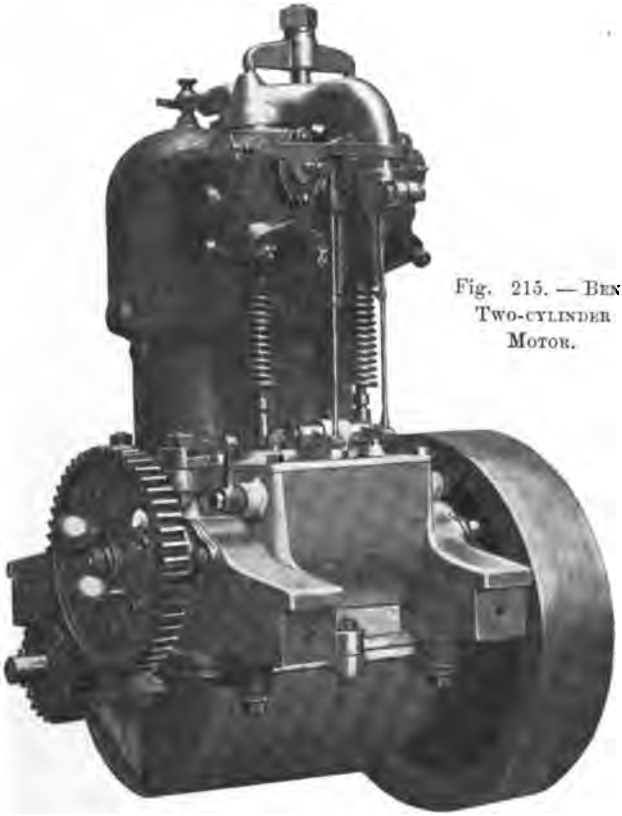


Fig. 215. — Benz Two-cylinder Motor.

bearings. The casing enclosing the gear wheels driving the cam shafts also covers the centrifugal force governor mounted upon the crank shaft. The exhaust cam shaft has a commutator on its front projecting end. The cam which makes and breaks the electrical circuit between battery and coil has two projections but only one contact spring, the same contact therefore being made twice during each revolution of the cam shaft. The inlet cam shaft carries special cams for operating the push rods acting upon the inlet valve spindles; the shaft has a long key-way so that it, together with the cams, can be moved longitudinally, although it is at all times driven by its spur wheel. The shaft is provided with a collar at its forward end, which is engaged by the forked end of a lever, whose other end is fixed to a spindle which is carried in bearings in the governor casing, and the sliding sleeve of the governor engages with a second fork lever which is fixed to the same spindle. The governor has not a spring, but when rotated it tends to force the inlet valve cam shaft A, Fig. 217,

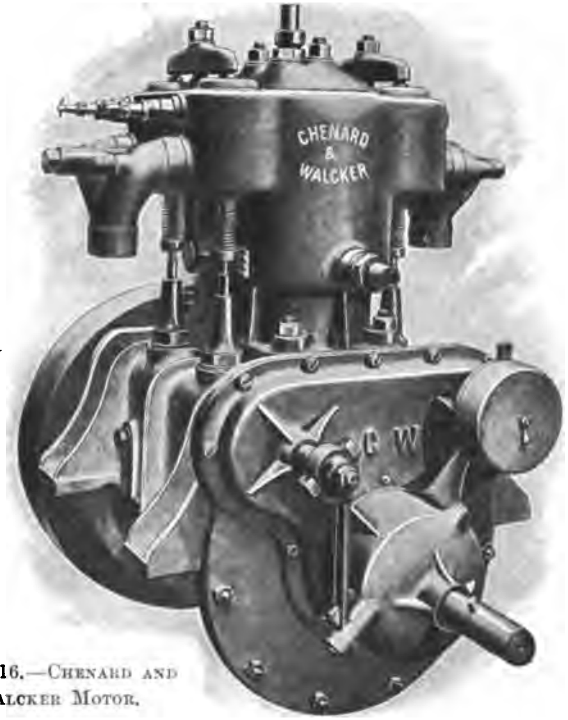


Fig. 216.—Chenard and Walcker Motor.

rearwards, and to therefore slide the inlet cams, so that a different portion of their services operates the inlet valves. The shape of the special cams is shown diagrammatically in the end and side elevations, Fig. 217. The cam projection at the one end, B, would open the inlet valve at the beginning of the suction stroke, but would almost immediately afterwards allow the valve to close. The other end of the cam, C, would open the valves at precisely the same point and to the same extent, but would hold it open until the intake stroke were complete. At intermediate positions of the cam, the valve would close sooner or later according to the longitudinal position of the cam shaft beneath the inlet valves. When the motor is first started, and if the controlling spring were adjusted for running at high speed, the left end, C, of the cam would be operating the inlet valves, and when

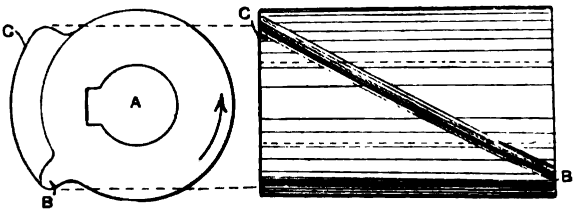


Fig. 217.—Chenard and Walcker Regulating Cam.

the speed of the motor increased the governor would tend to slide the cam along, reducing the quantity of mixture drawn into the cylinder, and consequenty reducing the force of each explosion. In practice, however, the controlling spring is not allowed to exert any pull when starting the engine, and consequently the cam shaft is caused to slide longitudinally owing to the action of the push rod on the tapered face of the cam, so that the right-hand end B is brought beneath the valve spindle, and a small quantity of mixture is admitted during each suction stroke. The extent to which the valve is opened is constant and therefore there is no throttle action on the carburetter, except such as is due to high piston speed. The *quantity* of air drawn through the carburetter during the suction stroke of the engine varies in the aggregate, according to the position of the cams, but the *rate* at which it passes through it during any particular part of the stroke is not affected by changes of position of the cam shaft. Owing to this, the richness of the mixture is not affected by the action of the governor anything like as much as with a throttle valve. A vacuum is formed in the cylinder during the working stroke, the compression is considerably reduced at the end of the next stroke, the initial pressure resulting from combustion is considerably less, and during the firing stroke the gases expand down to atmospheric pressure before the exhaust valve opens. Again, the quantity of mixture admitted to the cylinder is varied but slightly by changes of speed, whereas when a throttle valve is employed the effect of the throttle becomes less and less as the motor runs slower. The *Automotor Journal*, to whom this description and the accompanying diagrams are due, doubts whether this is altogether an advantage, for the effect obtained by throttling is often inconvenient if the force of the explosions becomes greater, as the speed is decreased owing to increased load. Perhaps, however, the advantages obtained, so far as the carburetter is concerned, entirely outweigh such a small matter. Were it not for the fact that the velocity of the air passing through the carburetter varies as the speed of the motor varies, this governing system, in conjunction with an ordinary float-feed carburetter, would give practically the same result, so far as constancy of mixture is concerned, as is arrived at with the Krebs carburetter, described on p. 141. The ignition plugs are screwed into the walls of the inlet valve chambers horizontally, and the insulated wires from each high-tension terminal of the coil are brought to them. The primary current passes through the coil twice during each revolution of the cam shaft; the one contact being necessary to produce ignition is in the one cylinder and the other in

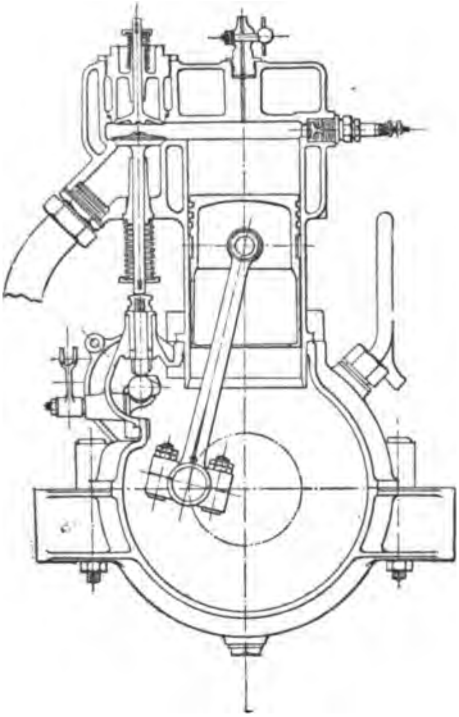


Fig. 218.—DECAUVILLE TWO-CYLINDER MOTOR.

the other cylinder ; on both occasions, however, the current finds its way across from one high-tension wire to the other across the spark points of both plugs, the current passing from one plug to the other through the cylinder casting. By this arrangement, greater synchronism between the two cylinders is obtained. The time of ignition is fixed, and the spark occurs slightly before the end of the compression stroke. The reason why back firing is not experienced when starting the motor is that the lead given to the ignition is slight, and the inlet cams are not admitting a full charge of mixture at that time. The method employed for governing the motor would be affected if the moment of ignition were to be varied. On a light load the moment of ignition could be advanced without causing pre-ignition, owing to the reduced compression in the cylinder, and because the charge fires less rapidly at lower compressions. The Longuemare exhaust-jacketed carburetter draws its air supply from near the exhaust pipe. At the normal speed of 900 revolutions per minute, 12½ b. h.-p. is developed, but the motor is so elastic that the speed can be less than 100 or as much as 1,200 revolutions per minute.

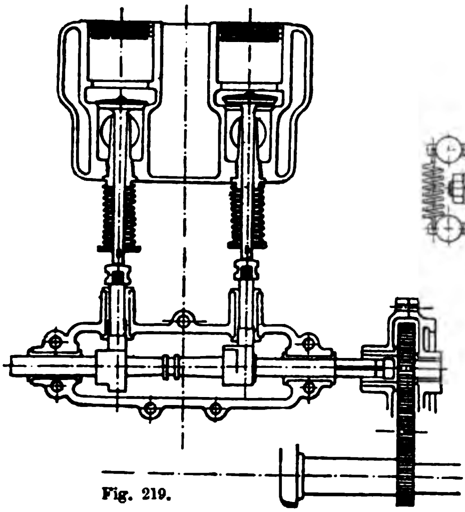


Fig. 219.

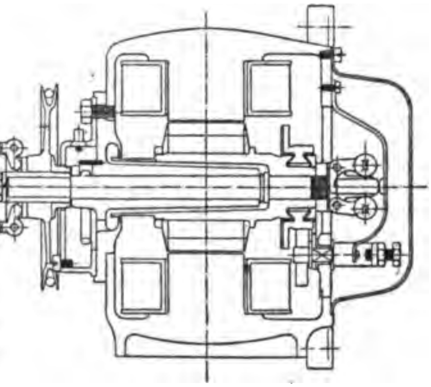


Fig. 220.

Fig. 219.—Decauville Exhaust Valve Lifter.

Fig. 220.—Decauville Ignition Dynamo.

The Decauville modern two-cylinder vertical motor is shown in cross section by Fig. 218. In this motor, the cylinders are cast in one piece, and the piston rods are arranged at an angle of 180°, and the bearing surfaces are of wrought steel, except those of the cylinder and pistons. The cylinder bore and piston stroke are 110 mm. (4·3 in.). The pistons, exceptionally long, project into the aluminium crank chamber at their lowest positions, and so assist lubrication, the oil being carried from the chamber to the cylinder walls; further lubrication is assured by dynamo-type rings, which constantly draw oil from two wells, one below the front bearing and one below the back bearing, and raise it into the bearings, through which it overflows on to the piston rod; from the base chamber the oil returns through a groove into the wells. The inlet valves are atmospheric, and the apparatus for working the exhaust valves is shown by Fig. 219 and is at one side of the motor; it can be removed without interfering with the cog-wheels. A governor works on the exhaust valve. Ignition is electric, and if desired, the current is furnished by a dynamo, belt-driven from the motor shaft, which is forged in one piece; a section of the Decauville dynamo is given by Fig. 220. The circulation of the cooling water is assured by a centrifugal pump, gear-driven by the motor shaft, and a Loyal radiator of the type shown by Fig. 168, p. 194, is employed. The Sthenos carburetter adopted is described on p. 121. This motor gives 10 h.p. at 1,000 revolutions per minute.

Another type of Decauville motor is of 16 h.p., and is quite new; it has four vertical cylinders, and the base of its crank chamber is made in one piece with the lower part of the gear box. Each pair of cylinders is cast in one, and both inlet and exhaust valves have mechanically operated valves, the two cam shafts being on opposite sides of the crank chamber. Bassée-Michel ignition plugs are used. The water jackets of the cylinders are divided into two parts by a vertical metal partition in the direction of the motor's length; and this partition prevents the water from passing across from one side to the other, except at the bottom of the jackets. The long pistons are again employed here, and the gudgeon pin is prevented from moving by a wide piston ring which does not touch the cylinder wall.

The Darracq four-cylinder motor of 12 or 20 h.p. takes the familiar form of two distinct castings, each comprising two cylinders. Both inlet and exhaust valves are operated mechanically. Immediately above the inlet valves the high tension ignition plugs fit horizontally into the valve chamber walls.

The Rochet-Schneider 20-h.p. four-cylinder motor has a peculiar system of making electrical contact with the ignition plugs, the current being supplied by a magneto. Knife switches are pivoted upon a spindle carried on, but insulated from, brackets formed on the top water-pipe. The inlet valves are worked mechanically, and other details conform to latest practice as indicated in the end view, Fig. 221, in which the magneto with carburetter behind it is shown to the left, and gear-driven pump and governor to the right. The method of driving the magneto is also shown clearly.

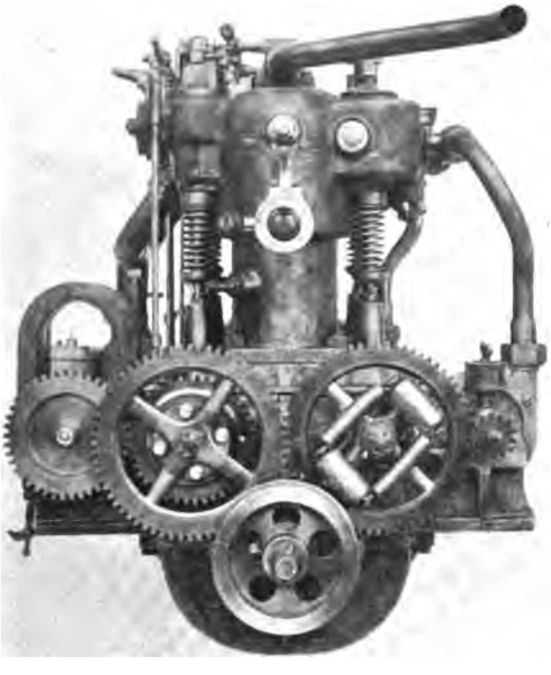


Fig. 221.—Rochet-Schneider Four-cylinder Motor.

The G. Richard vertical motor is made in several styles and powers, the standard sizes being 10 brake h.p., 12 h.p., 24 h.p., and 40 h.p. All these have a normal speed of 1,000 revolutions per minute. The first has two cylinders, with a bore and stroke of 100 mm. (3·93 in.); the second also has two cylinders, with a bore of 104 mm. (4·1 in.), and a stroke of 100 mm. (3·93 in.), and it can give on occasion 13 brake h.p.; the third and fourth have four cylinders, both agreeing with the second type in other respects, except that the 40-h.p. motor has a bore of 125 mm. (4·9 in.) and a piston stroke of 130 mm. (5·1 in.). These four motors are of practically the same construction. The atmospheric inlet valves are in the cylinder heads, and the low-tension igniters, fitted in the right-hand side of the heads opposite the exhaust valves, are operated by the usual cam shaft, but the moment of ignition is varied by a device acting upon the trip mechanism close to the igniters. The rotary gear-driven magneto fixed to the crank chamber is driven by a separate lay shaft on the right, this shaft also driving the lubricating oil pump. The G. Richard four-cylinder motors use the special carburetter described on p. 127.

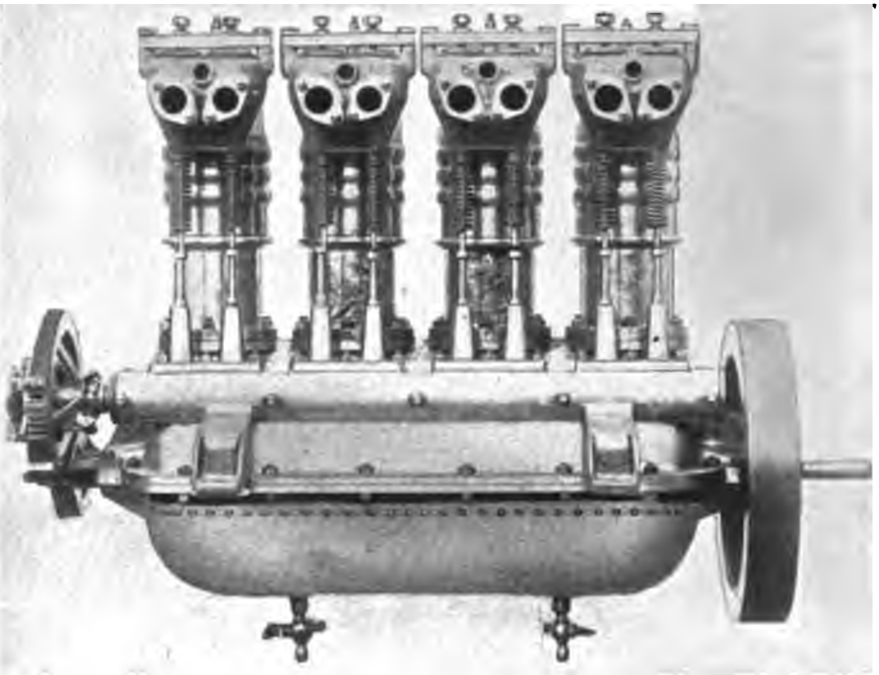
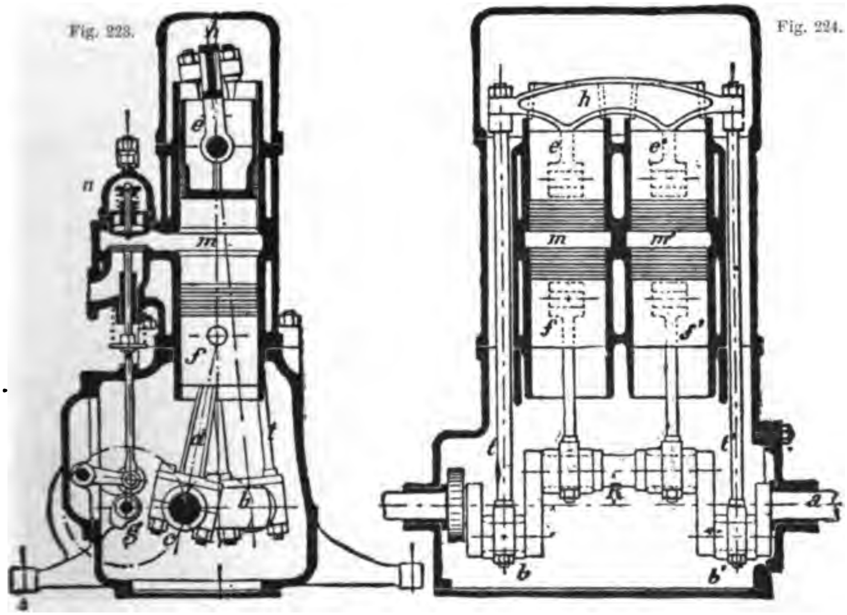


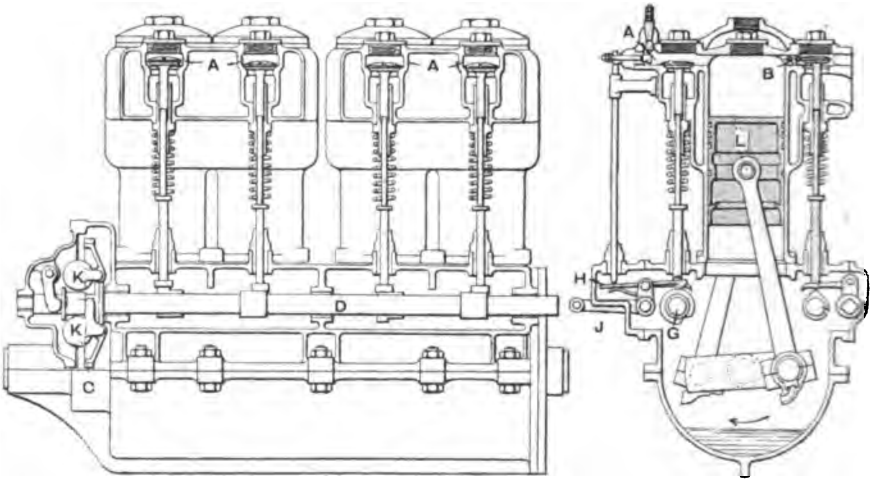
Fig. 222.—Tony-Huber Four-cylinder Motor.

The Tony-Huber new four-cylinder motor (Fig. 222) is on the new Panhard style, having a water-jacket of sheet metal, the pipe connections to which have an easily removable toggle-joint form of union; a rubber washer completes the joint, pressure being applied by an arrangement of bent wires, one of which forms a toggle lever. As illustrated, both the inlet and exhaust valves are operated mechanically, the rods worked by the cam being of large diameter, and their tops forming disc cams; the valve spindles rest on these, and there is an arrangement for simultaneously rotating the rods so as to vary the degree to which the valves are lifted.



Figs. 223 and 224.—Gobron and Brillié Petrol Motor.

The Gobron and Brillié motor, shown by Figs. 223 and 224, has two vertical cylinders side by side, with two pistons in each, *e f* and e^1 f^1, each pair working in opposite directions. The rods of the lower pistons drive the crank R; those of the higher pistons, by means of the bar *h* and the connecting rods *t t*, drive the cranks *b* b^1, which are at 180° from the first. The coupling of the higher pistons is thus heavier than that of the lower pistons, but in return the throw of the cranks *b* b^1 is smaller than that of R, and the difference is calculated so that the strains of the two sets of pistons perfectly equilibrate each other. All the motor vibrations appear to be overcome. The charges of oils measured by volume by the appliance described on p. 139, which is controlled by the regulator, are atomised in the suction pipe and mixed with air; the mixture admitted by the automatic valve n enters the channel below into one of the explosion chambers m^1 or m^2, and after compression is ignited electrically. An automatic commutator is placed on the secondary circuit and alternately sparks in each chamber with a single coil: the lead of ignition is regulated automatically by the lever for speed changing, the speed ranging from 250 to 1,000 revolutions per minute. The amount of water employed for cooling can be limited by aid of a radiator to 8 l. or 10 l. (14 pt. to 17·6 pt.).



Figs. 225 and 226.—Sections of Hautier Four-cylinder Motor.

The Gobron-Brillié motor dispenses with a carburetter; instead, a cone, upon whose face is cut a number of small recesses or buckets, rotates intermittently within another cone in such a manner that the petrol or alcohol supplied enters each of the buckets in a definitely measured quantity, each holding sufficient for one cylinder charge; the measurer is rotated by a small ratchet, actuated by a hit-and-miss lever, and controlled by an inertia governor. A later type of this motor encloses in a removable aluminium case the upper pistons and the bridge-piece carrying the connecting rods outside the cylinders. Each connecting rod is formed of two steel rods. Four drop brackets, brazed to the tubular frame of the car, carry the motor. The cam shaft is within the crank chamber, and a ratchet device operates a lubricator fixed alongside the cylinders for lubricating them and the moving parts. The governor regulates the petrol supply, the air supply, and ignition advance.

The Hautier motor is one, two, or four-cylinder, the last named (Figs. 225 and 226) consisting of two groups of two cylinders of 100 mm. (3·93 in.) bore, with a piston stroke of 115 mm. (4·5 in.) and a normal speed of 1,000 revolutions per minute; the speed may range from 1,500 to 200 revolutions. Fig. 227 shows the piston.

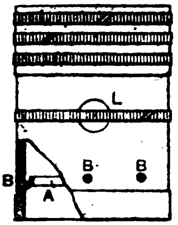


Fig. 227.—Hautier Piston.

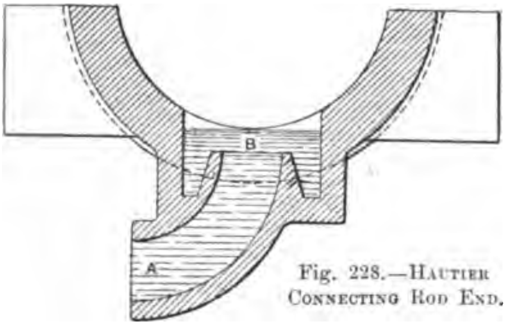


Fig. 228.—Hautier Connecting Rod End.

The mechanically operated admission and exhaust valves are identical, therefore interchangeable; the former are placed on the left and the latter on the right of the motor, and they are actuated by a similar set of cams. Each cam shaft carries at its end a toothed wheel worked at half-speed by the distribution pinion keyed on the crank-shaft. The inlet valve cam shaft also carries the ignition cams. Current is supplied by a magneto. However, not one of these three sets of cams—inlet, exhaust, and ignition—strikes directly the spindle it controls. The ignition cam G carries a hammer which falls suddenly into its notch at a moment varying with the forward or backward position given it by the lever. Lubrication is assured by a Dubrulle lubricator. The piston-rod head has a kind of spout, shown separately at A (Fig. 228), which scoops up the oil and carries a constant supply to the cup B, formed in the bronze bearing of the joint, so that the crank pin is always surrounded by a film of oil. This spout has a further purpose of regularly splashing the interior of the piston. The liquid redescends in a circular neck, A (Fig. 227), formed in the casting, whence it flows out through the holes B; the hole for the rod connection is shown at L. Thus the piston smears the cylinder with oil. The pin L (Fig. 226) of the piston is held in place by a fourth ring, which assures an air-tight fitting and avoids the use of set screws with their lock nuts and pins, which sometimes cause serious trouble. In Figs. 225 and 226, the former being an elevation on the inlet valve side, and the latter a vertical section, A shows the inlet valves, B the exhaust valves, C toothed wheel on cam shaft D, G the ignition cam, H hammer, J ignition regulation lever, K the governor acting on the inlet, and L the piston-rod pin.

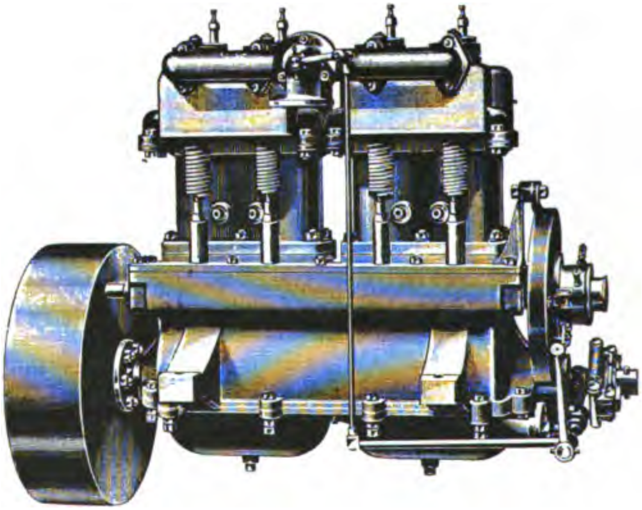


Fig. 229.—Brouhot Four-cylinder Motor.

The Brouhot four-cylinder motor is shown by Fig. 229; it is made in three principal sizes, 15, 20, and 40 h.p., and there is a two-cylinder motor of the same general design of 10 h.p. Its chief merit is its simplicity and strength, and the valves and parts are easily accessible by removing the hood. The centrifugal force governor is mounted on the crank shaft, outside the casing, and it throttles the intake as clearly illustrated. The cooling water is circulated by a pump, and ignition is electric. Only the exhaust valves are operated mechanically.

The de Dietrich (Turcat-Méry) motor may have either two or four cylinders, of which a section is shown by Fig. 230. The cylinders are in pairs and are bolted to an unusually long crank chamber, A, which has a plug, B, and hand-hole, C. The inlet valves D are atmospheric, and ignition low-tension magneto. Water is circulated by a pump chain-driven from the front end of the crank-shaft E, and if this should fail, circulation is automatic on the thermo - syphon system. In Fig. 230, F shows exhaust valve, G the exhaust and ignition cam shaft, H an oscillating shaft for advancing and retarding ignition, and J the water-jacket, with cock K.

The de Dietrich-Bugatti 24 h.-p. four-cylinder motor has its two pairs of cylinders each cast in one piece, and each casting then is enclosed in a circular aluminium casing, A, Fig. 231 forming the water jacket; inlet valves' E, exhaust valves D, and ignition plugs are in the cylinder heads, and the valves are operated mechanically by a cam shaft lying along each side of the crank chamber. The rods, whose weight is taken by springs H beneath the casting, are shown passing through A, and they serve to transmit the cam motion to the valves. The bevel-geared commutator M is necessary for the high tension ignition; magneto ignition also is said to be fitted. An automatic governor acts as usual on the throttle. The bore is 114 mm. (448 in.), piston stroke 130 mm. (5·12 in.), and the speed ranges between 250 and 1,400 revolutions per minute. Behind the honeycomb radiator G is a belt-driven fan. The water pipes leading from the tops of the jackets are shown at C.

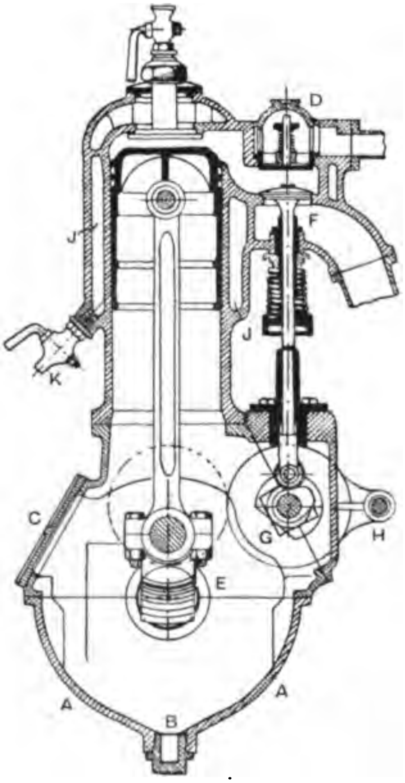


Fig. 230.—Section of de Dietrich (Turcat-Méry) Motor.

The Watsonia (Durkopp) vertical two-cylinder motor, shown in section by Fig. 232, has two cranks, A, set opposite one another, and made rigid with three internal fly-wheels, B, the shell of the clutch C, outside the crank chamber D, also acting as a fly-wheel. This arrangement gives good balance and smooth running. Other points deserving mention are as follows: The cylinders E are cast in one with their jackets, and the top flange pieces F are held down by tubular fittings, G, into which fit the ignition plugs H, the sparking points being thus in a separate chamber, as it were; contrary to what might be expected, the burnt gases do not collect in these separate chambers and do not interfere with ignition, whilst a probable advantage is the absence of soot on the sparking points. The pistons J and the forged connecting rods K are very slight. The aluminium crank chamber D is in two parts, one above and one below the axis of the crank shaft. Keyed to the crank shaft in front of the crank chamber is a helical spur-wheel, L, driving the cam shaft M by means of pinion N and toothed wheel O; this gear is enclosed in a casing, P, bolted to the crank chamber, and on the casing are two projecting studs supporting a sprocket wheel, Q, connected by chain to the starting-handle shaft. The sprocket wheel Q is mounted in bearings in a cross bracket, and engages with the crank shaft only when the sliding key R is pushed inwards, the key freeing itself when

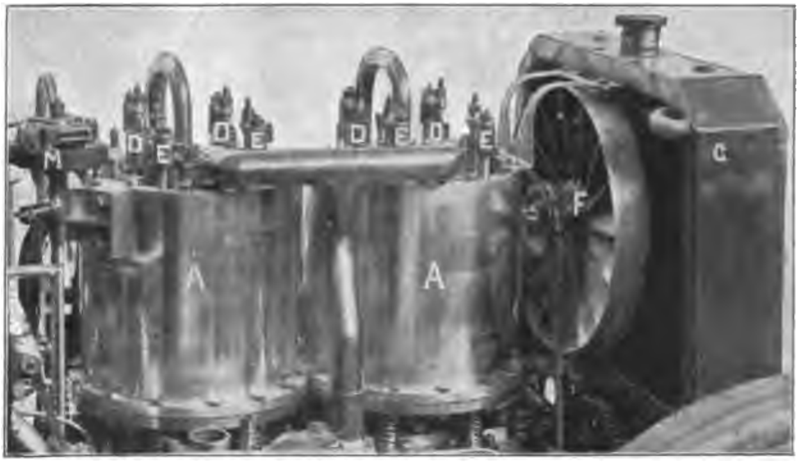


Fig. 231.—De Dietrich-Bugatti Four-cylinder Motor.

the motor starts. The larger spur-wheel O carries a centrifugal force governor, and the extreme end of the cam shaft M carries another spur-wheel, S, which through a shaft works a special kind of rotary pump. The governor simultaneously works a throttle which regulates the warm-air supply to the mixing chamber of the float-feed carburetter, and another throttle controlling the

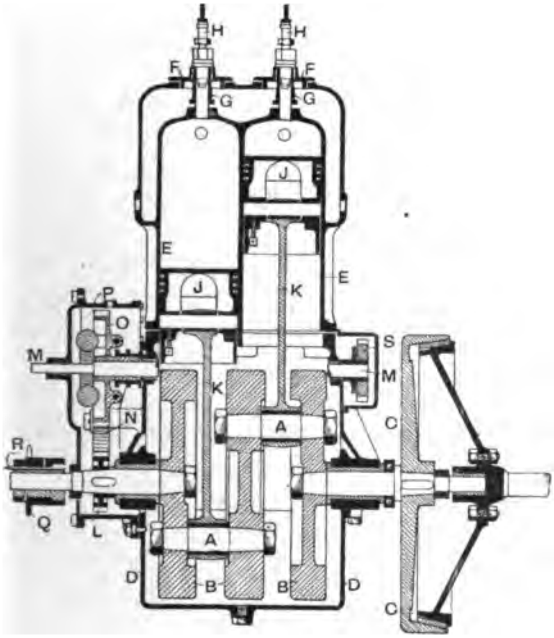


Fig. 232.—Section of Watsonia (Durkopp) Motor.

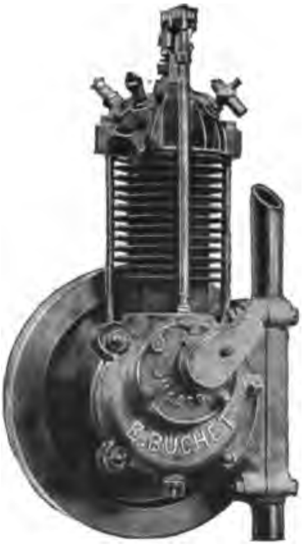


Fig. 233.—Buchet One-cylinder Motor.

passage of the mixture to the cylinders. The nominal 10-h.p. motor gives 13 brake h.p. it is said, whilst the four-cylinder motor, practically consisting of two sets each constructed on this system, and therefore containing six fly-wheels exclusive of the clutch, is rated at 15 h.p., though the actual output is probably much more.

The Charron, Girardot, and Voigt 1902 four-cylinder motor has atmospheric inlet valves, and is governed automatically by sliding the exhaust cams along their shaft and so cutting out one cylinder after another; also, an intake throttle is hand-operated. The lubricating pump is driven through spiral gearing by the rear end of the uncased exhaust cam shaft. In the 1903 motor, both inlet and exhaust valves are operated mechanically, the two shafts being encased and respectively driving the lubricating and water pumps through spiral gearing. The governor is on the front end of the inlet cam shaft, and the commutator on the forward end of the exhaust cam shaft.

The C. G. V. 40-h.p. eight-cylinder motor employs two carburetters, and by its use it is hoped to dispense with change-speed gear, which is feasible enough if the engine speed is low enough to take the car, when fully loaded, up the steepest inclines the car is, likely to have to negotiate. The multiplicity of cylinders should give a more uniform torque, but the difficulties of synchronising are great, and additional trouble in other ways is given.

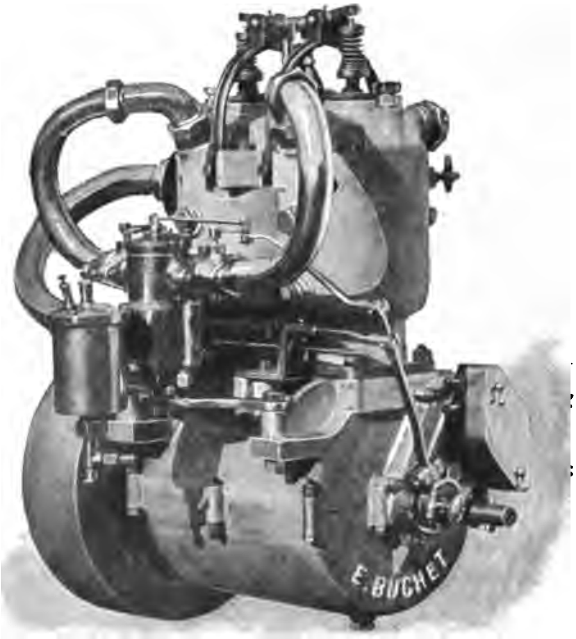


Fig. 234.—Buchet Two-cylinder Motor.

Buchet motors have come well to the front during the last two years, largely owing to their adoption on the Santos Dumont airship; a 15-h.p. motor employed for this purpose weighed only 91 kg. (200 lb.). The bicycle air-cooled motor (Fig. 233) is of 2¼ h.p., and weighs 13 kg. (28·6 lb.), the fly-wheel alone weighing more than half this; single-cylinder air-cooled motors are made up to 6½ h.p. Buchet water-cooled single-cylinder motors may be anything from 3½ h.p. to 9 h.p., and two cylinder motors are 8½ h.p. and 12½ h.p. The four-cylinder motor is practically identical with the two-cylinder motor in its details, and may be of 16, 24, 40, or 70 h.p. A typical two-cylinder motor, complete with all necessary connections, is shown by Fig. 234.

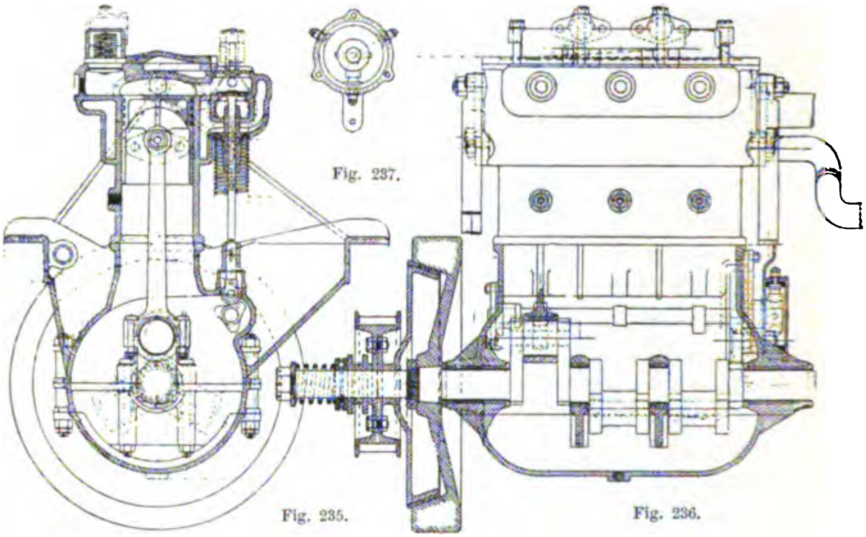
The Belgica one-cylinder and four-cylinder motors employ a float-feed device to keep a constant level of oil in the crank chamber, from which the moving parts of the motor are lubricated on the splash system.

The Hagen one-cylinder motor employed on the Hagen 2·5-ton lurry, built in Cologne, is of very substantial construction. Its normal speed is only 450 revolutions per minute, and the cylinder bore is 170 mm. (6·69 in.) with a stroke of 200 mm. (7·87 in.). The half-speed shaft is enclosed in the crank chamber, and is stout enough to transmit the whole of the power. For ignition there is a Bosch magneto. The carburetter can use either petrol or alcohol carburetted with 20 per cent. of petrol. The consumption of petrol is ·39 kg. (13·7 oz.) per h.p. hour. This quantity is equivalent to ·55 l. (·968 pt.) at a density of 0·7.

The Belle (Swiss) one-cylinder motor is really a vertical motor, but it is placed at an angle of 45°, with its crank-shaft lying transversely across the front of the voiturette frame.

The best known Italian motor is the F.I.A.T. (Fabrica Italiana di Automobili). The latest type has four cylinders, and the mechanically worked inlet and exhaust valves are on opposite sides, their cam shafts being hollow. There are the usual governor and accelerator, the rod of the latter passing through the exhaust cam shaft. The inlet cam shaft works the low-tension igniters, the ignition cams being acted upon by a central rod so as to vary the moment of ignition, the rod being controlled by a centrifugal governor mounted inside a spur-wheel which drives the magneto. The governor automatically advances the moment at which the the igniters break the circuit in the cylinders, and at the same time causes the magneto to generate the maximum current at corresponding moments. The system of lubrication is unusual. A pipe leads from the bottom of the dashboard lubricator to the circulating water system, and the oil floats upon the water and is forced up by it, flowing through sight-feed glasses to the feed pipes. A gauge glass indicates the level of the oil and water in the container, and when all the oil has been displaced by water this is drawn off by means of a cock.

A two-cylinder motor of some interest is employed on the Peerless (American) car. Its two pistons work on one crank at the expense of mechanical balance, though this method gives more regular ignition than does the opposite arrangement of the cranks. The half-speed shaft carries a centrifugal force governor from which a bell crank lever operates a double throttle valve in the induction pipes.



Figs. 235 and 236.—Sections of Brooke Three-cylinder Motor.
Fig. 237.—Brooke Commutator.

Examples of three-cylinder vertical motors will now be described.

The Brooke three-cylinder 10-h.p. motor shown in cross and longitudinal vertical section respectively by Figs. 235 and 236, is a British-made motor, introduced in its present form last year. It has a transverse position in the car (*see* p. 595), chiefly in order to avoid the use of bevel wheels in the transmission, and this arrangement does not give room enough for four cylinders. The motor resembles the car in being well thought out, and differing from Continental practice. Its governor is a special feature of the novelty, and has proved its efficiency. The three cylinders are cast in one piece with their heads, and this casting is bolted to three aluminium castings forming the crank chamber and base. Special bolts so hold the lower two castings that the lowest one can be removed readily and the pistons withdrawn or the crank-shaft bearings examined, without interfering with the cylinders or crank shaft. The middle casting carries two outside main bearings, and forms two short intermediate bearings between the three cranks. Although the motor is compact, the bearing surfaces for the connecting rods and for the crank shaft are ample, a result obtained by splaying the big end bearings of the outside connecting rods and placing the two outside crank pins at a greater distance apart than are their cylinders. The crank pins are set at an angle of 120° from each other. The fly-wheel at one end of the motor and the spur-wheel driving the half-speed shaft at the other end are fixed rigidly upon the solid forged crank shaft, which is coned for the purpose, small keys and lock nuts holding them in position. The exhaust cams are forged solid with a shaft inside the crank chamber. The commutator is at the fly-wheel end of this cam shaft, and is shown separately by Fig. 237. The cams are so arranged that an impulse is given at each two-thirds of a revolution. The inlet valves are atmospheric, though in a 14-h.p. motor they are worked mechanically; they are of the Estcourt type (Fig. 238) with two springs, of which the inner one does not act until the valve is lifted somewhat; the impact brings the nut on the valve spindle into contact with this inner spring, and the valve returns to its seating quickly and quietly. The exhaust passage communicating with the valves passes right through the three-cylinder casting from end to end of the motor, at one end having a pipe

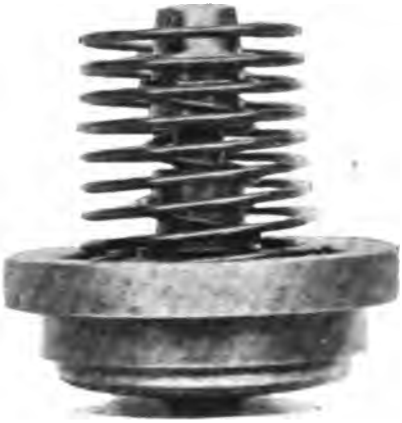
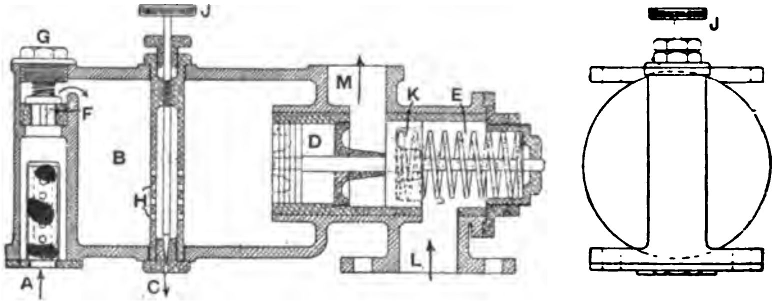


Fig. 238.—Estcourt Induction Valve.

connection to the muffler, and at the other end a connection to the special governor described below. The pistons are very long, but of thin light metal, and have ordinary cast-iron rings. The motor is fixed to the frame by drop brackets cast solid with one of the crank chamber castings. The cylinder bore is 90 mm. (3·54 in.) and the piston stroke 120 mm. (4·72 in.), and 10 h.p. is developed at a speed of 750 revolutions per minute.

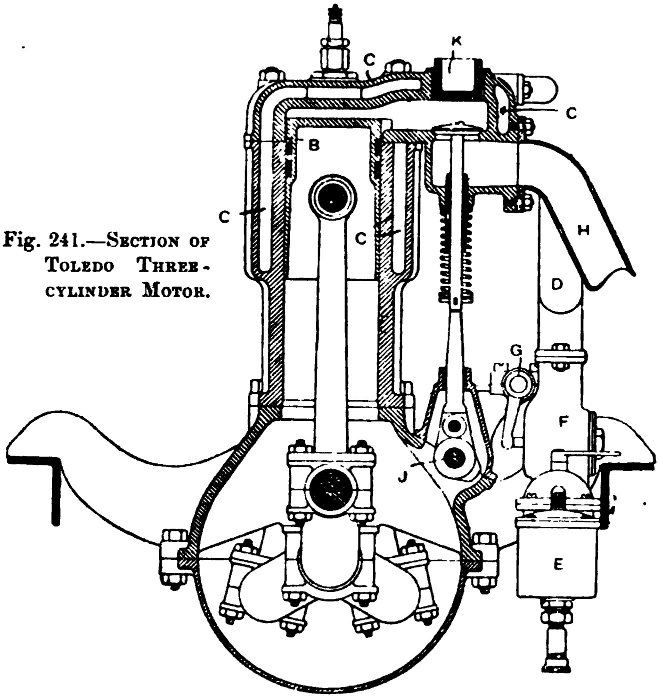


Figs. 239 and 240.—Brooke Exhaust-controlled Throttle.

The Brooke governor is shown in section and end view by Figs. 239 and 240. It acts by throttling the supply pipe between an ordinary float-feed carburetter and the inlet valves, and it is controlled by the pressure of the exhaust gases in the pipe connection referred to above. Naturally, the volume of exhaust gases, and therefore their pressure, must increase with the speed of the motor. A branch pipe, A, connects the motor exhaust with the chamber B, whose exit is needle-controlled at C; at one end of the chamber is a small piston, D, sliding in a short cylinder, and normally held on its seat by spring E, whose compression is adjusted by screw and lock nut. The entrance to chamber B is controlled by a check valve, F, and this again is held on its seat by a spring as shown. To adjust the relative pressure in the governor chamber B, either the supply of exhaust gases entering at A can be adjusted by the nut G, which regulates the check valve, or the rate at which the gases escape from chamber B through holes H and needle-valve C can be varied by the milled head J; actually the stem of this needle-valve projects for a distance equal to the diameter of the chamber. It will be seen that the displacement of piston D depends on the pressure within the chamber, and on the tension of spring E. The piston is directly connected with a piston throttle valve, K, which regulates the passage of the explosive mixture which passes from the entrance L to exit M. A guide carries the piston rod, and prevents the exhaust gases from leaking into the explosive mixture.

The Toledo (American) three-cylinder motor is shown in vertical section by Fig. 241, which shows the angle of 120° which the cranks make with each other. The power is 16 h.p., and the cylinder bore is 114·3 mm. (4·5 in.) and the piston stroke 140 mm. (5·5 in.). The mechanically operated inlet and exhaust valves are on the left side of the motor; there is but one mixture supply pipe and this branches to each cylinder, but there is a separate exhaust pipe to each. For ignition there are accumulators and an Apple (American) dynamo, which is a small four-pole enclosed machine having a centrifugal governor which regulates a friction clutch on its shaft, so that when the motor speed gets

Fig. 241.—Section of Toledo Three-cylinder Motor.



too high the dynamo armature slips; this prevents the dynamo overcharging the accumulators. Other details of the motor are much as usual. Fig. 241 shows a vertical section of the third cylinder, the same of the second cylinder valve chamber, and part of the first cylinder in elevation. Much in this figure is self-evident, but a few details may be referred to. B is the piston with connecting rod, C the water jacket, D inlet tube from carburetter E, F is the throttle valve chamber, G the throttle operating mechanism, H the exhaust pipe, J the cam shaft, operating both inlet and exhaust cams, and K the valve cover.

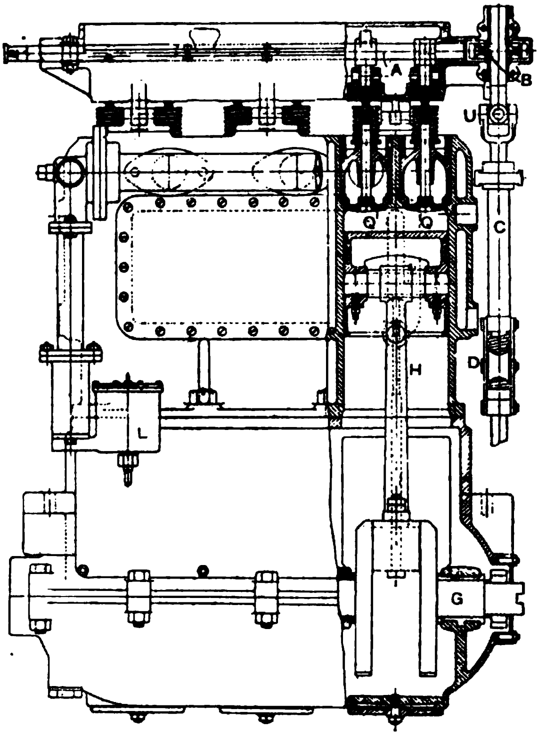
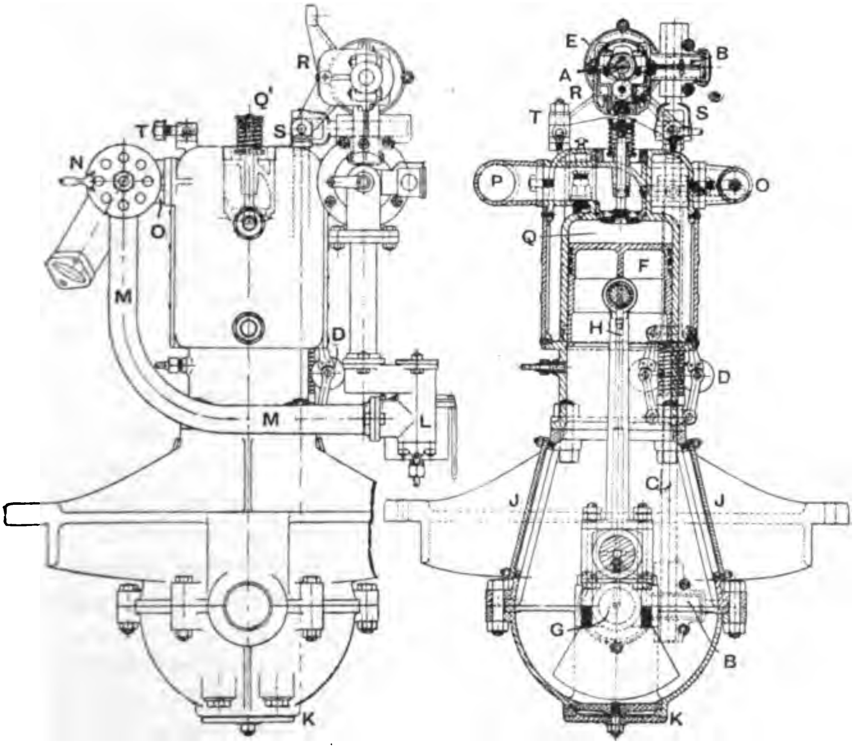


Fig. 242.—Front Elevation and Section of Maudslay Three-cylinder Motor.

The Maudslay 25 h.-p. vertical motor has three cylinders cast in one with their water-jackets, both bore and stroke being 127 mm. (5 in.), and the speed 800 revolutions per minute. Fig. 242 is a front elevation, Fig. 243 an end elevation with cam shaft casing thrown back, and Fig. 244 a vertical cross section. The inlet and exhaust valves Q Q^1, both mechanically operated, are placed in the heads above the pistons, and the cam shaft operating the exhaust valves is placed in a longitudinal casing above the cylinder heads, this being unique. The cam shaft A goes the whole length of the motor, and is operated by skew gears, B, on crank shaft and cam shaft, through a vertical shaft, C, carrying throttle governor, D. The rear end of the cam shaft carries the contact breaker, which is thus very easy of access, but high enough to avoid dust. The cam boxes E have inspection lids. Pistons, F, are trunk type as usual, and the crankshaft G, with pins at angles of 120° with each other, is carried in four bearings, and has an oil passage through its centre, there being a similar passage, H, in the forged and turned connecting rods. A pump, driven by the forward end of the crank-shaft by worm gearing,



Figs. 243 and 244.—End Elevation and Section of Maudslay Motor.

forces oil through these passages, and by means of oil holes in the crank shaft, the bearings, crank pins and gudgeons are lubricated. Two large inspection lids, J, are fitted to the side of the crank chamber, and others, K, are at the bottom. From the spray carburetter L, the intake pipe M (containing a governor-operated throttle, N) goes to the induction chamber O. The throttle N is a movable disc containing holes corresponding with holes in the fixed plate that forms the end of the induction chamber. The exhaust pipe P leads to a silencer at the back of the car. To relieve compression at starting a small cam on the crank shaft is operated, by a lever, and slightly opens the exhaust valve Q^1, so allowing some of the gases to escape. The casing R, containing the cam shaft, is hinged at S, and clamped by a nut at T; so, to examine the valves, the casing R is easily swung over into the position represented by Fig. 243. To allow of this the vertical shaft C has a universal joint at U.

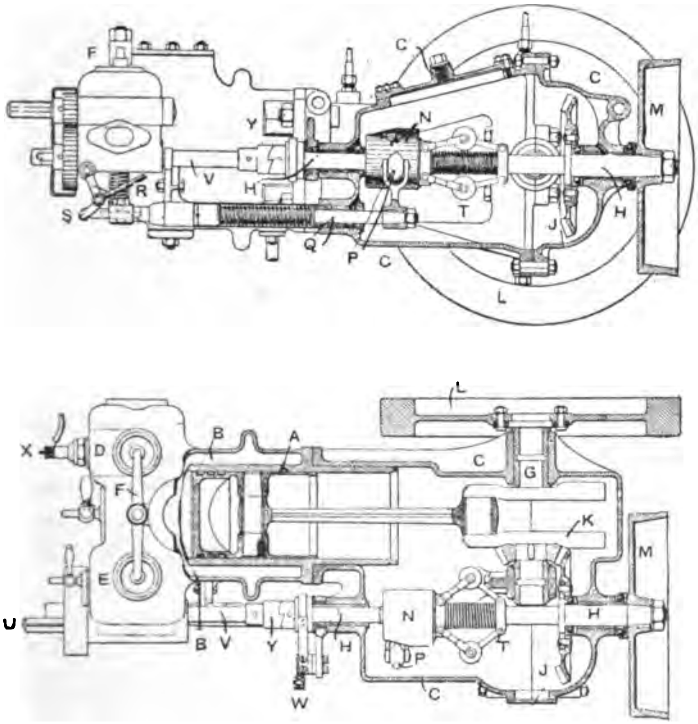
The Fischer motor, direct-coupled to a dynamo, on a petrol-electric omnibus (*see* p. 740) has three vertical cylinders bolted to a cast-iron crank chamber; the cranks are set at 120° to each other. Their bore is 120 mm. (4·75 in.) and the piston stroke 140 mm. (5·5 in.). Ignition is high tension electric, and the commutator is driven by bevel gear from the cam shaft; the contact springs are carried in a case which is free to rock about its axis and so vary the moment of ignition in much the usual way. The crank cheeks have counter weights. A float-feed spray carburetter is used. A pump is driven by a wooden connecting rod from a crank pin on the end of the cam shaft, and circulates the motor jacket water through a horizontal radiator underneath the vehicle. At a normal speed of 600 revolutions, the power is 10 brake h.p. The motor drives a 5-kilowatt dynamo.

The motor employed in the same manner on the Fischer lurry has four horizontal cylinders of the balanced type, the crank shaft being coupled direct to a 9-kilowatt dynamo; the cylinder bore is 14 cm. (5·5 in.), and piston stroke 15·24 cm. (6 in.).

The Duryea three-cylinder motor is described on p. 655.

The Packard (American) motor is almost alone in being of high power (12 brake h.p.) and yet having only one cylinder. The water jacket is of thin copper, and the cylinder, head, and crank chamber form one casting. For 1903, however, has been introduced a 25 brake h.p. motor, with four cylinders cast separately from the water jacket, which, like the crank chamber, is of aluminium alloy. The cylinder bore is 102 mm. (4 in.) and the stroke 127 mm. (5 in.), the speed being 1,000 revolutions per minute. This motor is shown in Figs. 686 and 687, p. 639.

The Gillet-Forest horizontal one-cylinder motor contains some novel departures from usual practice. 7 h.p. and 10 h.p. motors are the standard sizes, and the former has a cylinder bore of about 127 mm. (5 in.) and a piston stroke of 140 mm. (5·5 in.), its normal speed being 700 revolutions per minute and its top speed 1,000 revolutions, at which it gives about 8·5 h.p. The cylinder A (Figs. 245 and 246), jacket B, and head are one casting, and the cylinder mouth registers into, and is bolted to, the aluminium crank chamber C. The atmospheric inlet valve D and the exhaust valve E are got at by removing a nut and the bridge F.



Figs. 245 and 246.—Sections of Gillet-Forest Horizontal Motor.

The exhaust valve spindle projects down through the cylinder and is operated by a rocking arm, actuated by a cam shaft as will be described. The crank chamber C encloses the transverse crank shaft G, and a longitudinal shaft H, driven at half-speed from the former through bevel gear, J K. The crank shaft has a fly-wheel, L. At one end of the half-speed shaft H is the driving clutch M, and in the other direction it forms the cam shaft; N is a long, tapered, sliding cam, operating the lever arm P of the rocking shaft Q. At the extreme end, the rocking shaft, by means of another lever arm, actuates the exhaust valve spindle which projects, as has been said, right through the cylinder head. The rocking shaft can be slid lengthwise in its bearings by means of a lever near the driver's hand; the end of this lever R has a long foot S. The centrifugal force governor T acts by sliding the tapered cam towards itself when the speed increases, the movement of rocking shaft Q being correspondingly reduced. There is an ingenious arrangement for starting the motor. The starting handle is placed on the spindle U of a normally idle shaft, geared by spur-wheels with the shaft V, jointed to half-speed shaft H at Y, a one-way clutch being interposed between the spindle and its spur-wheel; the commutator W on the half-speed shaft immediately below the starting spindle is so arranged that the spindle cannot engage with its spur-wheel until ignition has been set to occur at its latest point. The ignition plug is shown at X.

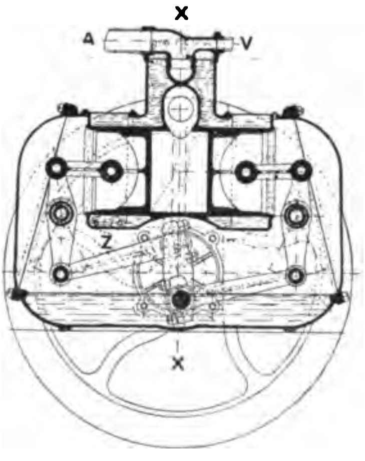


Fig. 247.—Mees Horizontal Motor.

The Mees petrol motor, used on the larger cars constructed on the Gustav Mees system, is shown in longitudinal sectional elevation by Fig. 247. It is of the so-called balanced type and consists of a single horizontal cylinder in which are two pistons, the central space in the cylinder between the pistons forming the combustion chamber. The power is transmitted to the main shafting, which is immediately below the centre of the cylinder, by means of rocking beams and connecting rods as shown by Fig. 247 ; and thus there are equal weights always at equal distances from the axis of symmetry, and a theoretically nearly perfect balance is obtained. The motor fly-wheel is very heavy so as to give a quiet, even movement. The motor appears to be simple, and its working parts are well balanced.

The Lanchester two-cylinder horizontal balanced motor has its leading principle made clear by Fig. 248 and 249, but it is a construction highly developed on somewhat original lines, of which only an indication can be given here. The two pistons and connecting rod link-work have their common centre of gravity about half-way between the two crank pins, which revolve in opposite directions; thus the centre of gravity of the moving parts moves to and fro along the axial line of the cylinders. To diminish vibration, there are two balance weights as shown, revolving in opposite directions. To take up the recoil of the impulse, the two fly-wheels, identical in all respects also, revolve in opposite directions. The cooling by forced draught is described on p. 196. The ingenious valve gear is shown by Figs. 250 and 251. Practically, one mechanically operated valve on each cylinder works both inlet and exhaust, though there are actually two valves. A is the motor cylinder port, B the exhaust port, C the feed port for the wick carburetter connection (*see* p. 116), D the main valve operated by a lever worked off the cam shaft, and E E^1 the combined feed-exhaust

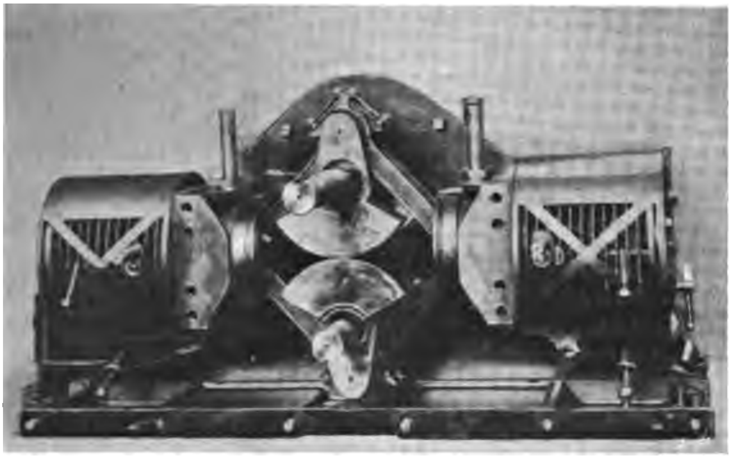


Fig. 248.—Lanchester Horizontal Motor.

valve, operated by another lever through the medium of an inertia governor, which, until a certain speed is reached, allows its blade to engage with the end of the valve stem, the "catch plate." This allows the admission of a fresh charge, but above a certain speed the governor does not act upon the spindle and the supply of gas is stopped until the speed is reduced. E, Fig. 250, shows the period of exhaust, the arrows representing the gases leaving the cylinder; E^1, Fig. 251, shows the period of induction, the arrows representing the ingoing charge. Ignition is low-tension, the current being furnished by a magneto, which, together with the scheme of the electrical connections, is shown by Fig. 252. The magneto is built into one of the fly-wheels, a neat and economical arrangement. The ignition plug is of quite a special kind, its form being shown roughly in Fig. 252. Lubrication is very thorough; tubes conduct the oil to the various parts in quantities measured by means of pockets in the lubricator spindle, which is driven through an intermediate shaft by means of worm gearing. Further details of ignition, etc., are given on pp. 676 to 683.

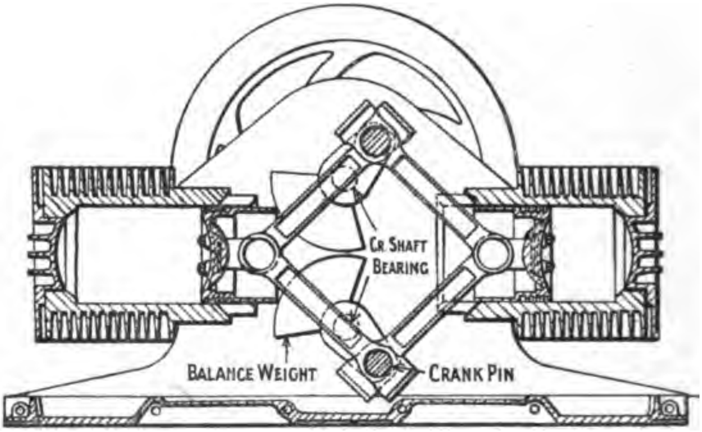
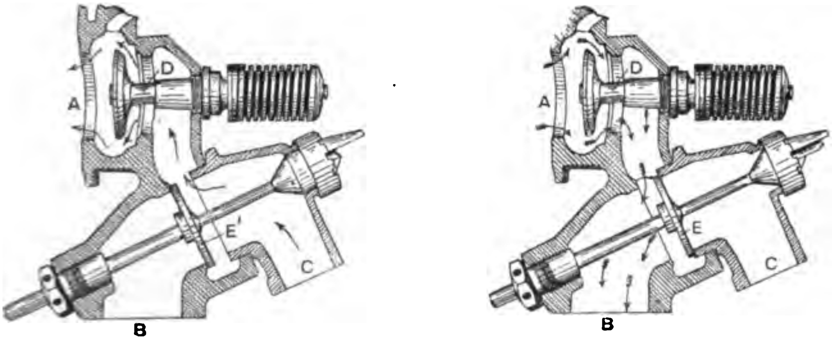


Fig. 249.—Diagram of Lanchester Horizontal Motor.

The Bardon motor is made in three sizes, 12 h.p. two-cylinder and 8 h.p. and 5 h.p. one cylinder. The 12 h.p. car is illustrated by Figs. 715 and 716, p. 666 and the following letters have reference to those illustrations. The motor A is placed transversely, and each of its two cylinders contains two pistons, thus forming actually four cylinders, with two combustion chambers. There is an enclosed crank shaft at each side of the car. A fly-wheel, B, is on each side of each crank chamber, C, and one of the four fly-wheels carries the centrifugal force governor D, which cuts out one or both of the exhaust valves as the motor speed increases. The front fly-wheel to the left carries a chain wheel connected with a sprocket on the starting handle shaft, E. The crank-shafts are shown at F. The inlet valves are close together above and in the centre, the ignition plugs are one before and one behind them; a new motor has mechanically operated valves. The vertical exhaust valves are on the outsides of the cylinders. The inlet valves are taken out by removing two nuts and lifting out a flange having a downward projecting sleeve, and the exhaust



Figs. 250 and 251.—Lanchester Valve: Positions for Exhaust and Admission.

valves by removing two nuts and lifting out the complete flanged valve. The cam shaft lies across the top of the motor, and is driven by large spur-wheels on the right-hand crank-shaft; it carries an exhaust cam at each end and the enclosed electric ignition commutator at its centre, the cams operating their valves through rocking shafts. Spring brushes press upon the commutator and can be rocked about the cam shaft for advancing or retarding ignition; a double coil with tremblers is used in connection with the ignition plugs. A Dubrulle lubricator on the dashboard is belt-driven from the left-hand crank-shaft, and supplies oil to all the motor bearings, and the crank chambers C have oil-tight covers. The Bardon 8 h.p. single-cylinder motor has the same general features, but the new 5 h.p. single-cylinder motor is placed longitudinally, not transversely, and the two crank-shafts, worked by the two pistons, are interconnected through bevel gearing by a first-motion shaft of the change-speed gear.

The James and Brown two-cylinder horizontal motor has its cylinders cast in one, the fly-wheel being between them. The valves are opposite to each other, and at right angles to the centre line of cylinders. The motor forms one piece of mechanism with the transmission gear, and the distribution of the parts is decidedly novel, as made clear by Fig. 419, p. 414, which shows both motor and transmission. With a bore of 101·6 mm. (4 in.), stroke of 152·4 mm. (6 in.), and a speed of 500 revolutions per minute, the power is 9 h.p.

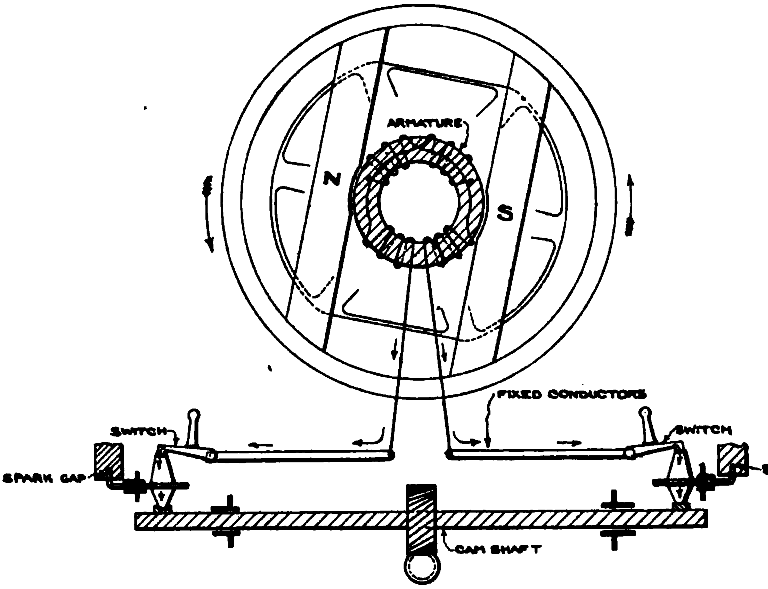


Fig. 252.—Lanchester Magneto Ignition System.

The Hermes 15 h.p. horizontal two-cylinder motor, shown in section by Figs. 253 and 254, has a bore and stroke of 5 in. and 5½ in. respectively ; the cylinders not being quite in line with one another, straight connecting rods, A, may be employed. The cranks are set at an angle of 180°, and the normal speed is 750 revolutions per minute. An ordinary float feed spray carburetter, B, is used, and the high tension ignition system has double pole sparking plugs, C. The inlet valves D and exhaust valves E are placed at the top and bottom of the cylinders respectively, there being no pockets formed to give unnecessary clearance. The jackets F are cast in one piece with the cylinder, and are so formed that the largest body of water is around the combustion chamber. The water circulation is maintained by a positive gear-driven pump. In Figs. 253 and 254 G is the flywheel, H the clutch, J two-to-one pinion, K the intermediate wheel, L the two-to-one wheels for the exhaust valve gear, M the exhaust valve rocking levers, N oiling rings for crank pins, and O water outlet. In Fig. 254, P is a part of the channel-steel main frame, and Q shows the cross tubes which carry the motor and gear.

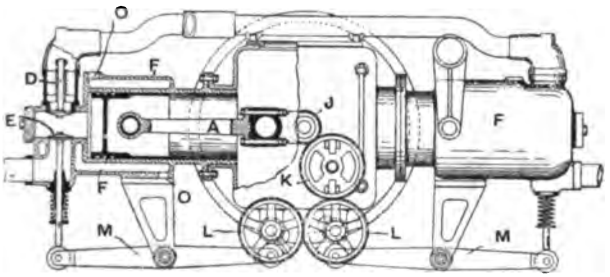


Fig. 253.

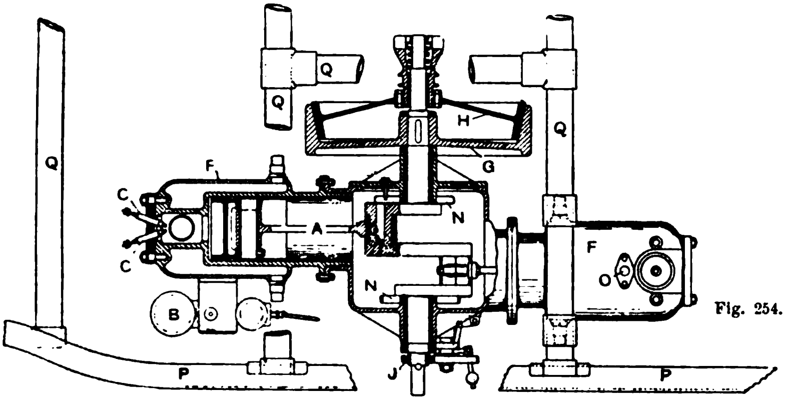


Fig. 254.

Figs. 253 and 254.—ELEVATION, PLAN AND SECTIONS OF HERMES MOTOR.

The Albion two-cylinder balanced motor is Glasgow-built, and its general design is novel, as shown by Fig. 254, which is a general view of the 8 h.p. type. The cylinder covers, containing the atmospheric inlet valves, are not water-jacketed, but the exhaust valves are. Cast in one piece with the crank chamber is a lower chamber containing the transmission gear. An inertia type governor inside the crank chamber acts on the inlet, and is connected to the accelerator, which permits the speed to be increased from the normal 700 revolutions to 1,000 revolutions per minute. Current for the electric ignition comes solely from an Albion magneto (Fig. 255) mounted directly on the motor shaft. A 10 h.p. motor of this type also is made; the Albion 12 h.p. motor is the same as the above in general features, but the inlet valves are operated mechanically, and a Murray centrifugal force governor replaces the inertia governor and accompanying gear; this allows a range of speed of from 250 to 950 revolutions per minute.

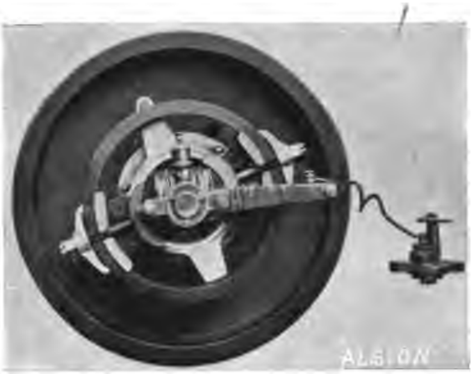


Fig. 255.—Albion Motor and Magneto.

The Meredith two-cylinder motor is horizontal, the cylinders being nearly in line with each other; the crank chamber is between them. The half-speed shaft operates the exhaust valves and the ignition commutator, and the inlet valves are atmospheric. A de Dion-Bouton carburetter is employed. The cylinder bore

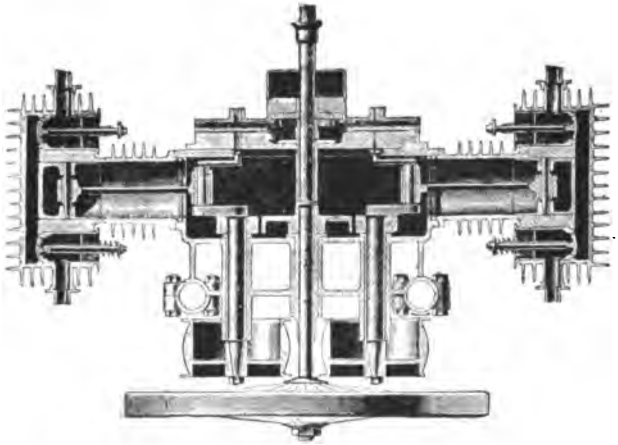


Fig. 256.—Turgan and Foy Petrol Motor.

is 114·3 mm. (4·5 in.) and the piston stroke 127 mm. (5 in.), and 10 brake h.p. is given at a normal speed of 700 revolutions per minute.

The Turgan and Foy two-cylinder motor for cars and voiturettes is shown in section by Fig. 256, and the object of the peculiar construction is to obtain improved balancing. Each piston works upon a separate crank-shaft, but both of the crank-shafts gear with a common central shaft, which they drive at half their own speed. In both the belt-driven and chain-driven petrol cars produced by the above firm the motor lies transversely across the front.

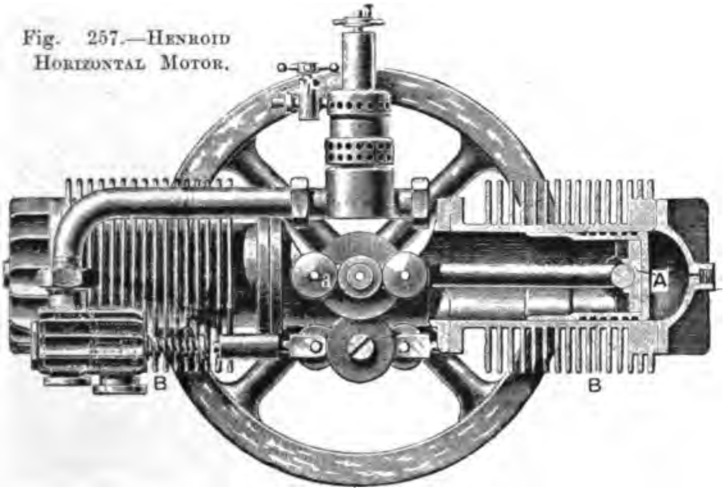


Fig. 257.—Henroid Horizontal Motor.

The Henroid motor (Fig. 257) has two horizontal opposite cylinders, whose pistons act on cranks keyed at 180° on the motor shaft between them; the two move inversely, and equilibrate each other. The inlet and exhaust valves form a distinct part from the cylinder. The carburetter is of the distributor kind, as described on p. 138, and only at the instant of compression produced by the piston in each cylinder is the carburetted mixture completed and made fully explosive. Cooling is obtained merely by special flanges, and the makers say that this suffices for their various motors, which range from 2 h.p. to 10 h.p. Ignition is electric; and the motor is regulated by keeping the exhaust valves open when the motor tends to race.

The Friedman (American) motor has two horizontal cylinders, bore 95·25 mm. (3·75 in.) and stroke 101·6 mm. (4 in.), the speed of 1,000 revolutions giving 7 brake h.p. The cylinders are in line with each other, and the connecting rods are straddled. The fly-wheel is the special feature, this having its front surface plated thickly with copper and driving a friction-wheel; transmissions of this kind, which are of doubtful efficiency though presumably giving great elasticity in speed, are described on p. 420. This motor has mechanically operated inlet valves, and its carburetter is described on p. 117, and its exhaust silencer on p. 204.

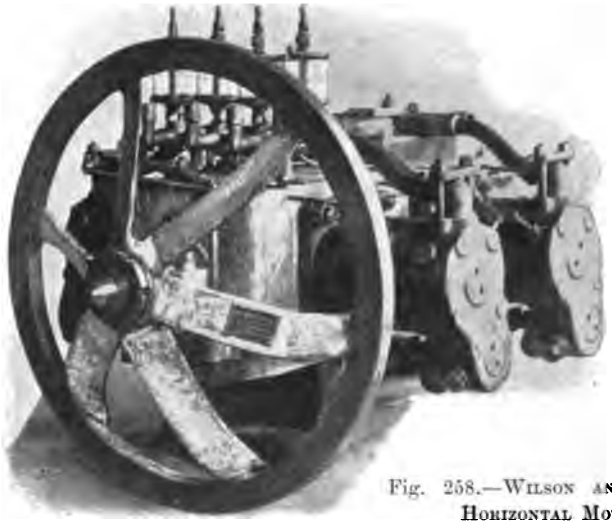


Fig. 258.—Wilson and Pilcher Horizontal Motor.

The Wilson and Pilcher petrol motor is of the four-cylinder balanced type (*see* Fig. 258), the 12 brake h.p. size having cylinders of 89 mm. (3·5 in.) bore and 95·25 mm. (3·75 in.) stroke. This is one of the most silent motors yet produced, and its details are interesting. The special piston ring used is shown by Fig. 259; a portion of the ring A, close to the usual split B, is cut away, and a tongue piece, C, has a projection, D, fitting loosely in the slot formed in the ring and serving to break the usual joint. The tongue piece C lies in a somewhat deepened portion of the groove of the piston itself, and fits between it and the ring; a tooth, F, lies in a deeper cavity, and prevents the ring moving round the periphery of the piston. This device reduces the leakage of the charge past the piston. An ingenious form of commutator also is employed. The atmospheric inlet valves employed are shown by Fig. 260. The spring A is so wound, and the pin (passing through hole B) which secures the nut C in place on the valve spindle D is so arranged, that the pin cannot be shaken out. The spindle has a special shape of screw thread to resist the tapping action always present.

The Ader motor is somewhat of a return to an early Daimler design: its cylinders, two or four, are set at 45° from the upright, that is at 90° to each other (*see* Fig. 261), which shows the two-cylinder type.

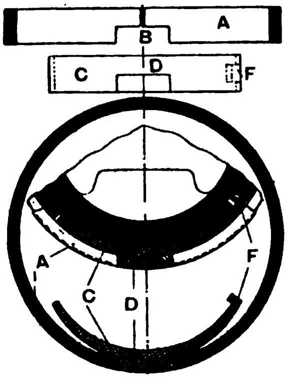


Fig. 259.

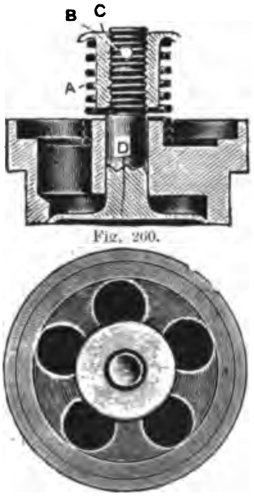


Fig. 260.

Figs. 259 and 260.—Piston Ring and Inlet Valve of Wilson and Pilcher Motor.

This is an interesting motor, and the section, Fig. 262, shows it clearly. The pistons A have connecting rods B, both working on the one crank pin C, secured to fly-wheels D, which are mounted, one each side, on the motor shaft E. Cam H actuates the spindle of exhaust valve K, whilst the inlet valve L is atmospheric. I is the ignition cam, and M the ignition plugs, forming a right angle with the cylinders. A water circulating pump, N, is driven by the spur-wheel O on the motor shaft, and there is an oil pump, not shown. The charge arrives at S, and the exhaust leaves at T, and an inspection plate, P, is provided over the valves. The combustion chamber and top part of the cylinder are water-cooled. A governor actuates a throttle much as usual. The four-cylinder type is newer, but does not differ much from this. The biggest two-cylinder motor made has a bore and stroke of 100 mm. (3·937 in.), a weight of 95 kg. (209 lb.) and develops from 10 to 12 h.p.; the biggest four-cylinder motor made has the same bore and stroke, weighs 175 kg. (385 lb.), and gives about 24 h.p.

The two cylinders of the Cottereau 7 h.p. and 10 h.p. motors also are inclined to each other, but the angle between them is only half what it is in the Ader motor. The piston rods are connected to the same crank-pin between two internal fly-wheels, and there is the usual external fly-wheel clutch. The suction stroke of one cylinder synchronises with the combustion or working stroke in the other, and this theoretically is very efficient, as the power is applied to the crank shaft from one cylinder just as the negative work in the other one is being done. In the 7 brake h.p. motor, the bore is 85 mm. (3·34 in.) and the stroke 105 mm. (4·13 in.); these

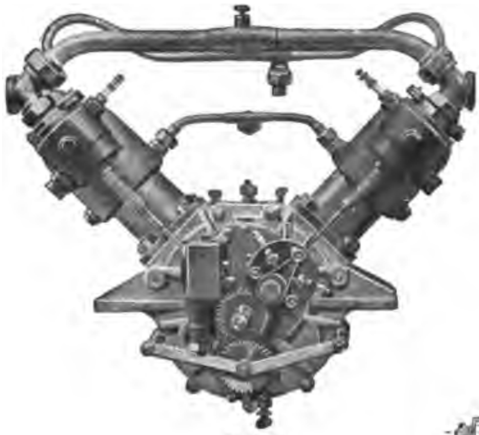


Fig 261.

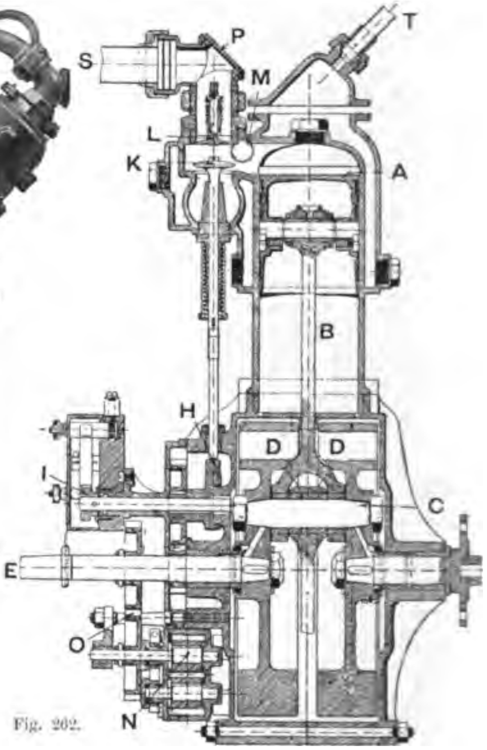


Fig. 262.

Fig. 261.—Ader Motor.
Fig. 262.—Section of Ader Motor Cylinder.

are 90 mm. (3·54 in.) and 110 mm. (4·33 in.) respectively in the 10 brake h.p. motor. The speed of both is 1,200 revolutions per minute. The Cottereau 16 brake h.p. motor has four vertical cylinders, bore 92 mm. (3·62 in.), and stroke 120 mm. (4·72 in.), the speed being 900 revolutions per minute.

Petroleum motors require to be designed with a view of overcoming at least three disadvantages—the tendency of heavy oil vapour to recondense between the moment it leaves the carburetter and the moment of ignition, the probability of the oil being only pulverised and not vaporised, and the risk of incomplete combustion producing a smoky exhaust of very bad odour; add to these disadvantages the reduced range permissible in the proportions of the charge. If the first three can be surmounted, there will be available a motive agent cheaper, more easily obtained, in some respects safer (though petrol spirit is safe enough with ordinary care), and of greater heat value than petrol.

The Roots petroleum motor is shown in sectional elevation by Fig. 263 and in horizontal section by Fig. 264. Its chief feature is the paraffin vaporising device which forms part of it. A platinum ignition tube, A, is enclosed in a vaporiser, B, and both at starting are heated by a blow lamp and afterwards kept hot by an oil Bunsen burner. The vaporiser is a gun-metal cylinder, with spiral passages in its walls, through which the air passes to the automatic inlet valve C. A grooved rocking valve rod D conveys oil from the supply-pipe both into the hot air passage and to a burner E; thus the quantity of oil is positively measured. The oil for the burner passes down a feed pipe, F, in which it becomes heated on its way to the burner. Air (at a pressure of about ·7 kg. per cm.^{2}; 10 lb. per sq. in.) from a chamber, G, near the crank chamber, flows through the feed pipe H and maintains the necessary flame for heating the tube and vaporiser. A supplemental air valve leads direct into the cylinder end. The pressure in the air chamber, which has a blow-off valve, is maintained from the closed-in crank chamber, there being a non-return valve between the two. The cooling water for the cylinder jacket circulates through a coil of piping, J, surrounding the fly-wheel K, and in the Roots runabout there is also a radiator between the front wheels. A governor acts on the reciprocating mechanism supplying the oil, but always allows a little to pass so as to minimise the risk of a miss-fire when the governor ceases to act.

The Koch motor is another of those that can be fed with

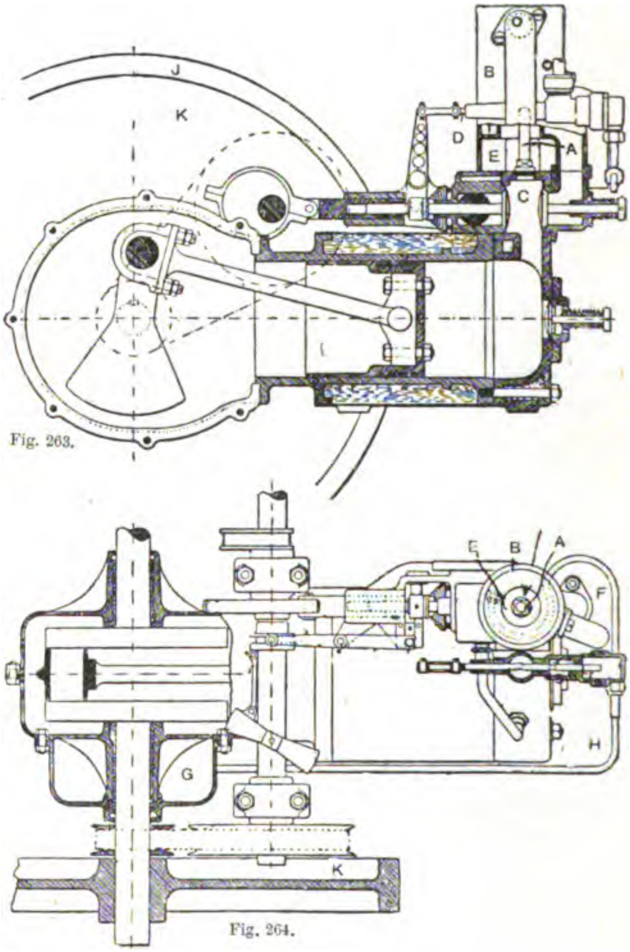
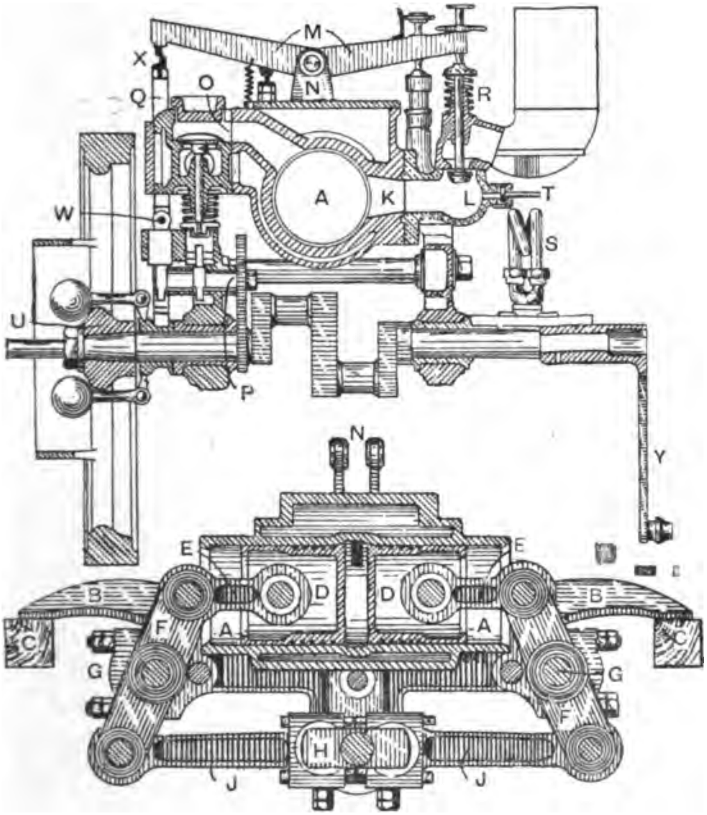


Fig. 263.

Fig. 264.

Figs. 263 and 264.—Sections of Roots Petroleum Motor.

petroleum, as well as with petrol spirit. In the horizontal cylinder two pistons work symmetrically in opposite directions and drive the motor shaft by aid of two systems of connecting rods (*see* Figs. 265 and 266); when these rods are balanced all other parts are. The maker asserts that this motor does not cause vibration. The petrol spirit or petroleum arrives with the air in the explosion chamber, where the two are mixed without any carburetter. Figs. 265 and 266 are longitudinal and cross sections of the Koch motor. A single water-jacketed cylinder A is placed transversely in the rear



Figs. 265 and 266.—Sections of Koch Petroleum Motor.

part of the vehicle, and is mounted on the framing B, supported by C. The two pistons D are connected by rods E to the rocking levers F, which are mounted on gudgeons G. The rocking levers are connected to the crank H by the connecting rods J. The space between the pistons, when at the end of their instroke, forms the expanding or explosion chamber, the igniting chamber K being shown to the right of the cylinder A in Fig. 265, in which

L shows the admission valve, which is worked by the rocking lever M, pivoted at N. O is the exhaust valve. By means of pinions, the shaft P is made to revolve at half the speed of the main shaft. One of the cams on the shaft P works the exhaust valve O, and the other works the rod or stem Q, which normally engages with the end of lever M. On the suction or aspiration stroke the rod Q lifts, and the other end of M depresses R, thus opening the valve L, which admits air and a few drops of petroleum. The chamber surrounding L is heated by a lamp (not shown) placed near S, this lamp keeping the ignition tube T incandescent. The petroleum is vaporised, and the explosive charge ignited on the completion of the compression stroke. Thus, there is no carburetter. Governing is affected by a hit-and-miss device closing the admission valve when required. A ball governor U, on the main shaft, engages by means of a collar, V, with the rod or stem Q, which is articulated at W. On the upper end of Q, and also on the end of the lever M, are fingers X, the fingers missing contact when the speed increases and the governor-balls open. The lever M and the valve L, therefore, do not work until the speed is reduced, and so fresh petroleum is not admitted to the combustion chamber. Y (Fig. 265) is the winch handle for starting. The 6-brake h.p. motor consumes from 2·44 l. to 2·98 l. (4·4 pt. to 5·25 pt.) of petroleum per hour. This is at the rate of from ·40 to ·49 l. (·73 to ·87 pt.) per horse-power hour.

The new stationary petroleum motor made by Mr. R. O. Allsop has one horizontal cylinder, working on the usual four-stroke cycle, and alongside it is a pump cylinder, whose piston is worked directly by a connecting rod from the crank shaft. A measured quantity of oil is injected into the pump cylinder with air and is compressed, allowed to expand, and then forced into the motor cylinder, the motion and the resultant heat thoroughly vaporising the oil spray, but the mixture is much too rich for there to be any risk of spontaneous ignition in the pump cylinder. As the charge passes to the motor chamber on the return stroke of the pump piston, it automatically draws in the auxiliary air necessary to combustion. The inventor does not think there is a chance of the oil recondensing before combustion. At starting ignition is by tubes, but later it is done automatically by the hot cylinder walls.

To complete the descriptions of the four-stroke-cycle motors there remain to be described the small motors for motor cycles and voiturettes, which, as a rule, are well designed, and are interesting.

The de Dion-Bouton motor is diagrammatically represented by Figs. 267 and 268, in which A is the carburetting tank; B air-inlet tube; C metal plate; D float; E motor cylinder; G stem of exhaust valve, S^1; H silencer; J worm to heat carburetter; K driving pinion keyed on fly-wheel shaft and gearing with a spur wheel mounted on the rear axle; M handle of steering bar controlling the electric circuit for sparking; N igniting device for explosive mixture; O blow-off tap for air; P accumulators; R tap for air inlet or for explosive mixture; R^1 motor inlet tap; S S^1 inlet and exhaust valves; T induction coil; U mechanical contact breaker or the induction coil. A long piston, with three segments, moves in the vertical cylinder; the connecting rods and disc crank, forming

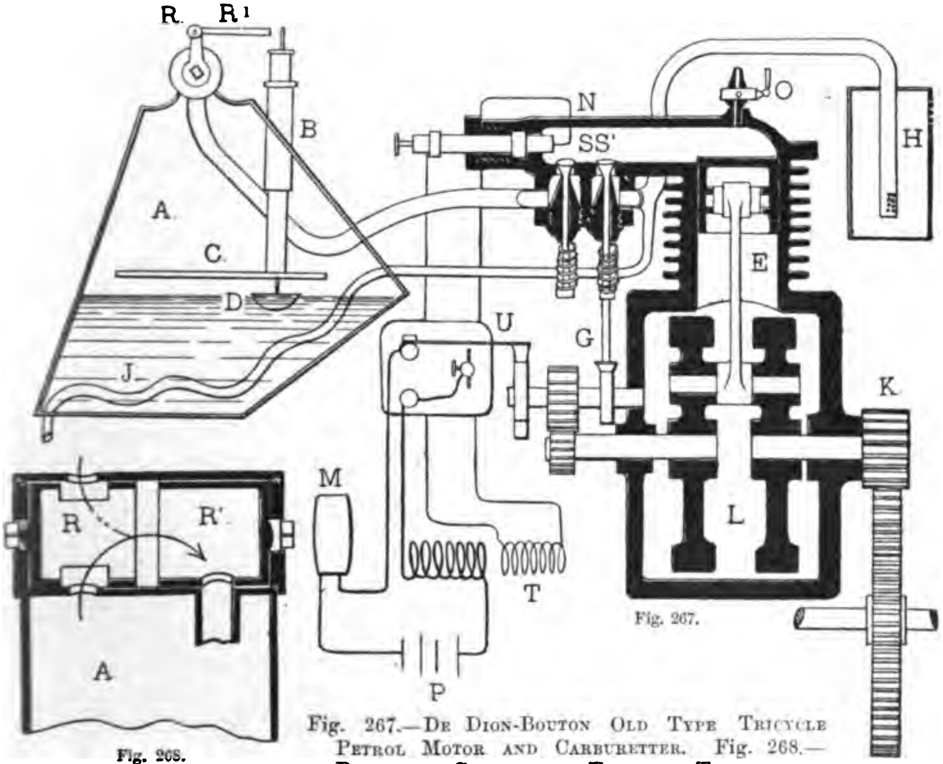


Fig. 267.

Fig. 268.

Fig. 267.—De Dion-Bouton Old Type Tricycle Petrol Motor and Carburetter. Fig. 268.—Details of Carburetter Tank and Taps.

a fly-wheel, are enclosed in an aluminium case containing oil. There is no governor. The electric ignition has the variant described on p. 166. The cooling is by flanges. For the 1¼ h.p. type the cylinder has a diameter of 58 mm. (2·3 in.), and a piston stroke of 70 mm. (2·75 in.), and the normal number of revolutions is 1,400 per minute. By increasing the bore to 66 mm. (2·6 in.) the power is raised to 1¾ h.p., and the thickness of the cylinder, then, is only 3 mm. (0·12 in.). It has 16 flanges projecting 19 cm. (7·5 in.), forming hoops. In some models the inlet valve is not placed as in Fig. 268, by the side of the exhaust valve, but above (*see* Fig. 269). The inlet valve and its seat are simply placed above the suction hole, on a flat support, with an asbestos washer, not shown in Fig. 269. They are covered by a bent pipe, through which the carburetted gas enters. All is maintained by a bell-shaped piece, with open sides, a bayonet fastening being employed, this latter device greatly aiding inspection of the valves. Owing to the radiation caused by the relatively large valve, and by the current of air passing through its openings, the bell assists in the cooling of the valve and the inlet nozzle; at each suction a greater weight of gas enters the apparatus, because its volume remains constant, and the temperature is less; thus the power of the motor is increased.

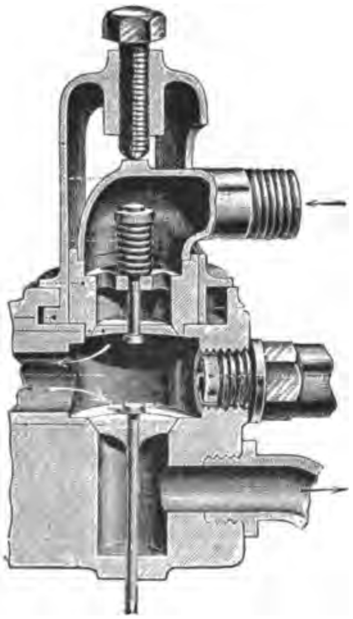


Fig. 269.—Dome of de Dion-Bouton Old Type Tricycle Motor.

The de Dion-Bouton new type of bicycle motor is shown in general view by Fig. 270, and in vertical section by Figs. 271 and 272. It is very compact, being only 40 cm. (15·75 in.) high, 14 cm. (5·5 in.) across, and 10 cm. (3·9 in.) wide, this narrow construction allowing the distance between the pedals to be reduced and so give greater convenience and comfort. A novel feature is the method of driving the half-speed shaft, which instead of being parallel to the main shaft is at right angles to it, and is driven by spiral gearing from the fly-wheel K. The periphery of K has a worm, as shown in the section Fig. 271, and so the fly-wheel forms the driving gear-wheel, which engages with wheel P on the cam shaft, the worm being correctly shaped to run the cam shaft at the usual half-speed; this arrangement allows the cam shaft to be in the same vertical plane as one of the two fly-wheels; and also it permits the contact breaker M, carried on the end of the cam shaft, to be mounted in the position illustrated. The radiating flanges or ribs adopted in the old type (*see* Fig. 267, p. 277) have been abandoned as regards the cylinder walls, but some of peculiar shape are retained at the head, where the heat is greatest. The valves and the ignition plug are as usual; the inlet valve is fixed in position by a threaded sleeve, so that the mixture pipe can be turned round into any desirable position before screwing tight. The exhaust valve is operated by a horizontal

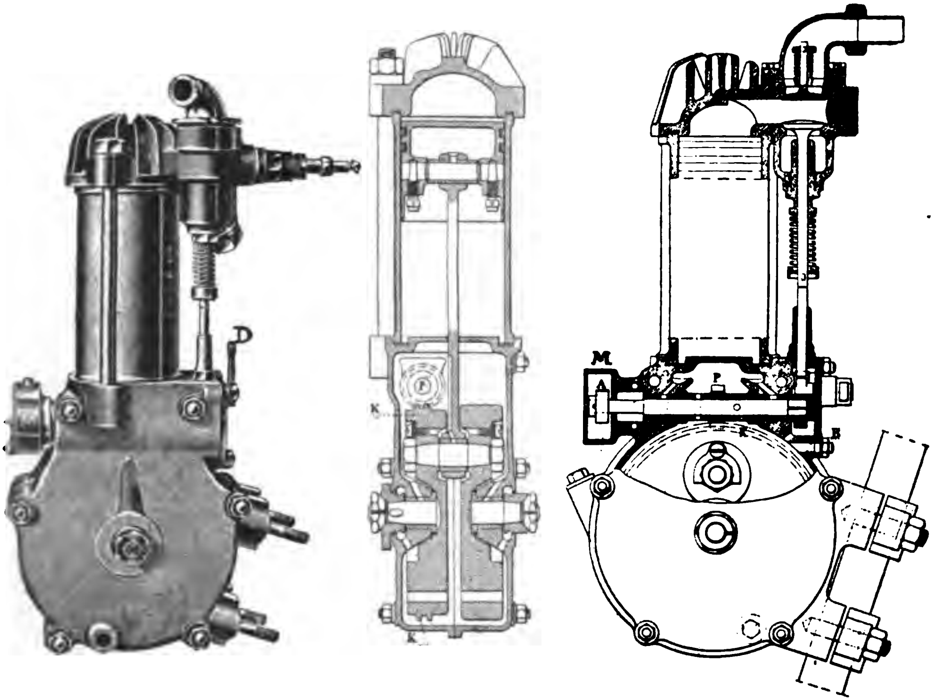


Fig. 270. Fig. 271. Fig. 272.

Figs. 270—272.—General View and Sectional Elevations of de Dion-Bouton New Bicycle Motor.

lever, lifted by cam B, Fig. 273; cam C can be displaced by the lever D, Fig. 270, in such a manner that the roller is raised clear of the cam B, and then carried up on to an inclined plane in the casing, the exhaust valve then remaining open. The ignition cam A is fitted on the opposite end of the half-speed shaft. The contact-breaker M is now of metal, not of insulating material, and forms part of the general electric connections; upon it are mounted the metallic contacts, insulated from it. The motor is fitted with sockets for securing to the down tube of the bicycle frame, but these may be replaced by collars for fixing the motor in any other position. The motor weighs 10 kg. (22 lb.), has a bore of 62 mm. (2·44 in.), a piston stroke of 70 mm. (2·75 in.), and its normal speed varies from 1,500 to 2,000 revolutions per minute, its power then being 1¼ h.p.

The new Minerva bicycle motor is illustrated in part sectional elevation by Fig. 274, in which the method of mechanically operating both the inlet and exhaust valves is at once apparent, the casing over the valve rod cams, etc., having been removed. S is the inlet valve spindle, and P the exhaust valve spindle, the valves themselves being separated by partition G, and being accessible by unscrewing the plugs above them. The charge enters at H, and the exhaust leaves at I. The end of the motor shaft is shown at O. The push rods V Q project through the casing and slide in guides, W R, in line with the valve spindles. The inlet valve rod V is lifted by the direct action of cam M on spindle N, and the exhaust valve rod Q through the ball-crank lever U, carried on the pin T. On the casing that covers this gear is a small rocking case, carrying the contact-breaker; this rocking case is connected by a simple bent lever with the spindle of the cam X immediately underneath the cam-gear casing. This cam is so set that by means of the projection Y on the bell-crank lever the exhaust valve is lifted as soon as ignition is advanced to its greatest possible extent; thus, if the timing lever is moved too far, the exhaust valve at once is lifted. The contact-breaker is shown separately by Fig. 275, in which cam D is carried on the end of the half-speed shaft E, corresponding with the shaft N in Fig. 274. The cam is cylindrical except for the projection F. The spring G, carrying the platinum contact H, is secured to block K by screw M. When the spring is deflected by the cam, the contact H touches the point of screw J, held in block L, and so completes the electrical circuit to the coil. The ignition plug is in the head of the motor (it cannot be shown in Fig. 274), and cooling is by the flanges shown. The attachment for the lubricating oil pipe is at Z, and the waste oil outlet at Z^1, Fig. 274.

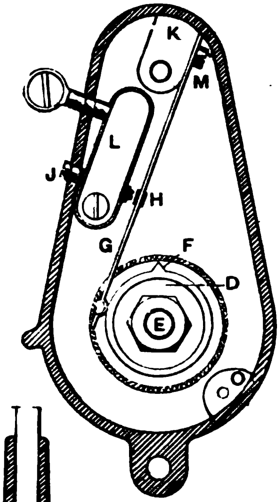


Fig. 275.

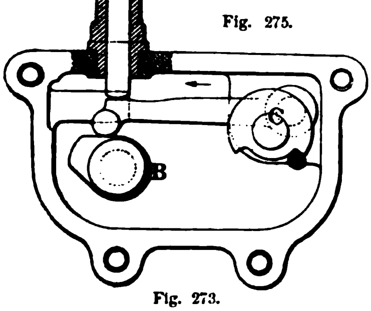


Fig. 273.

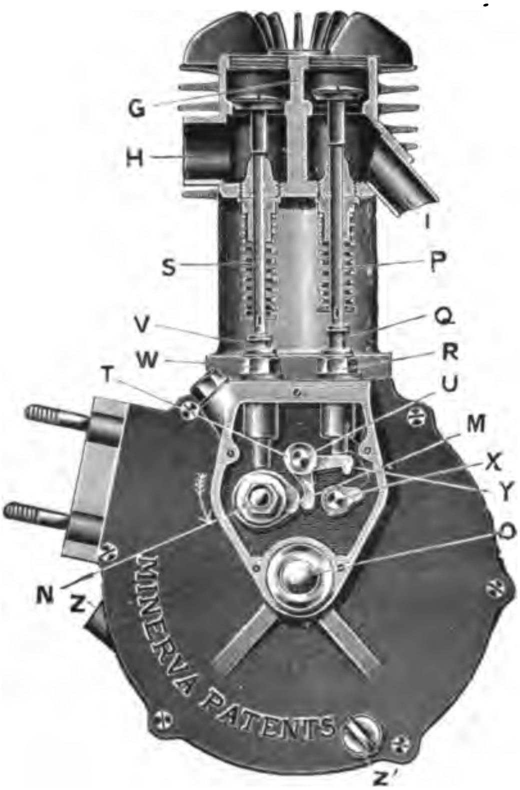


Fig. 274.

Fig. 273.—De Dion-Bouton Exhaust Valve Lifter. Fig. 274.—Minerva Bicycle Motor. Fig. 275.—Minerva Contact Breaker.

One type of Gaillardet motor is distinguished by the form and size of the flanges (*see* Figs. 276 and 277). The cylinder of the 2¾ h.p. motor has a bore of 80 mm. (3·15 in.), the piston stroke being the same, and a consumption of from 0·27 l. to 0·4 l. of petrol spirit per horse-power hour, the number of revolutions being about 1,800 and 2,400 per minute.

In one type of Aster motor, around the cylinder head and the valves are flanges, cast solid with them, and around the cylinder are copper flanges, the superiority of which over iron is stated on p. 201. Usually the Aster motor is of 2¾ h.p. Some types of Aster motor are wholly water-cooled (Fig. 278) and some have a mixed system as illustrated by Fig. 279, in which the head is water-cooled and the cylinder wall air-cooled by corrugated flanges.

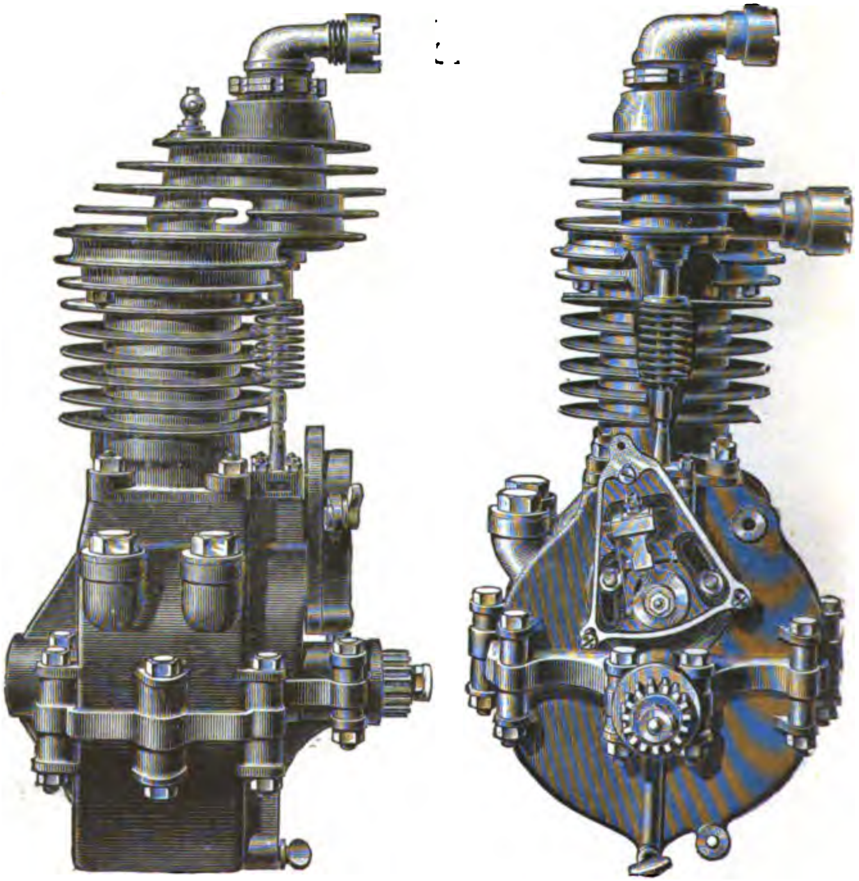


Fig. 276. Fig. 277.

Figs. 276 and 277.—Gaillardet Air-cooled Motor.

The Humber new bicycle motor is shown by Figs. 280 and 281. It is built up on four rods over which slide trunnions carrying the crank-shaft bearings, a plate serving to hold the lower end of the cylinder and the upper face of the crank chamber, the cylinder, cylinder head, and the necessary distance tubes. It is evident, then, that this embodies new ideas of construction. The rods terminate top and bottom in a pair of lugs, by means of which the entire motor is bolted to suitable projecting brackets on the framework of the machine. The crank chamber is of aluminium and in two parts, and serves merely as an oil-tight casing to

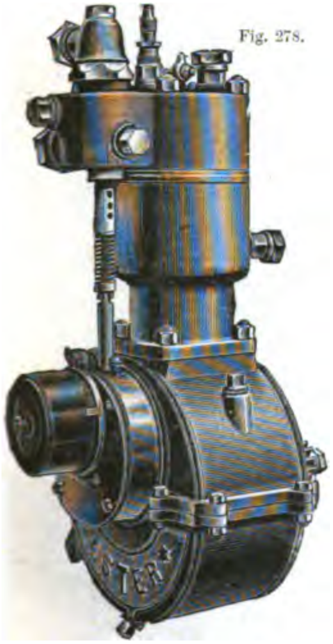


Fig. 278.—Aster Water-cooled Motor.

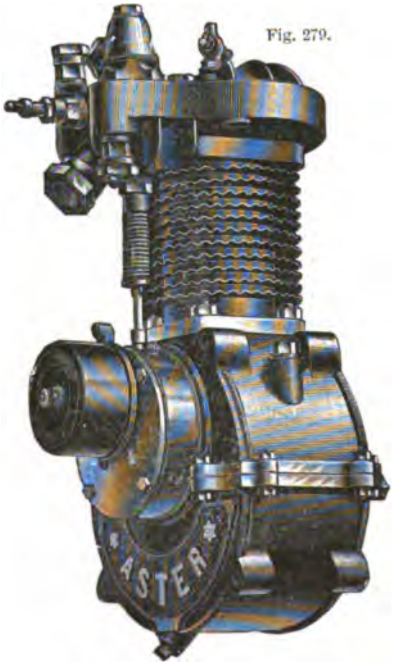
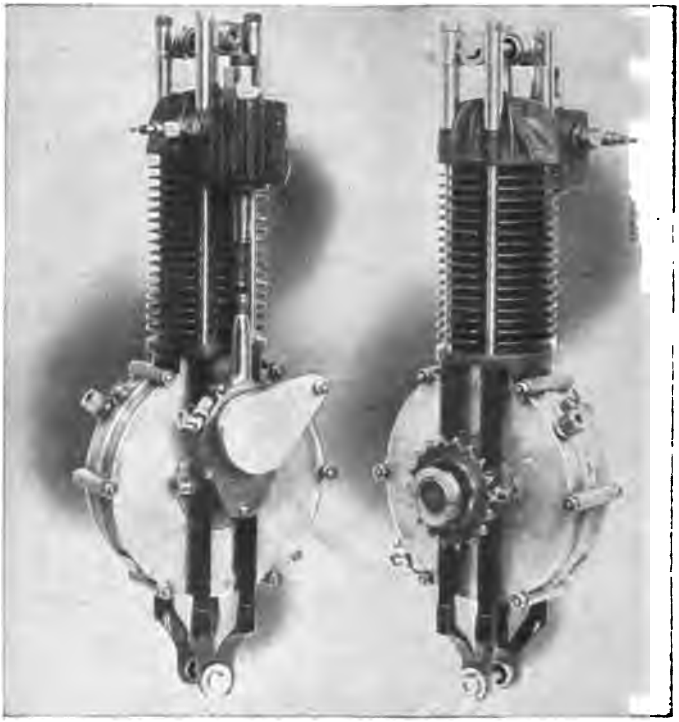


Fig. 279.—Aster Motor with Mixed Cooling.

retain the lubricating oil. The half-speed exhaust cam and the contact maker and breaker are on the right-hand side of the crank chamber, on the other side being the driving sprocket, which chain-drives a larger sprocket mounted about the bottom bracket, concentric with the pedal shaft, but free from it. A second chain passes from a smaller wheel attached to this sprocket back to a corresponding larger wheel carried on the rear hub. The cylinder bore is 66·6 mm. (2·625 in.) and the piston stroke 76·2 mm. (3 in.), and at a normal speed of 1,800 revolutions per minute the motor develops 2 h.p. The motor is placed in an inclined position, and actually replaces the front upwardly sloping tube of the bicycle.

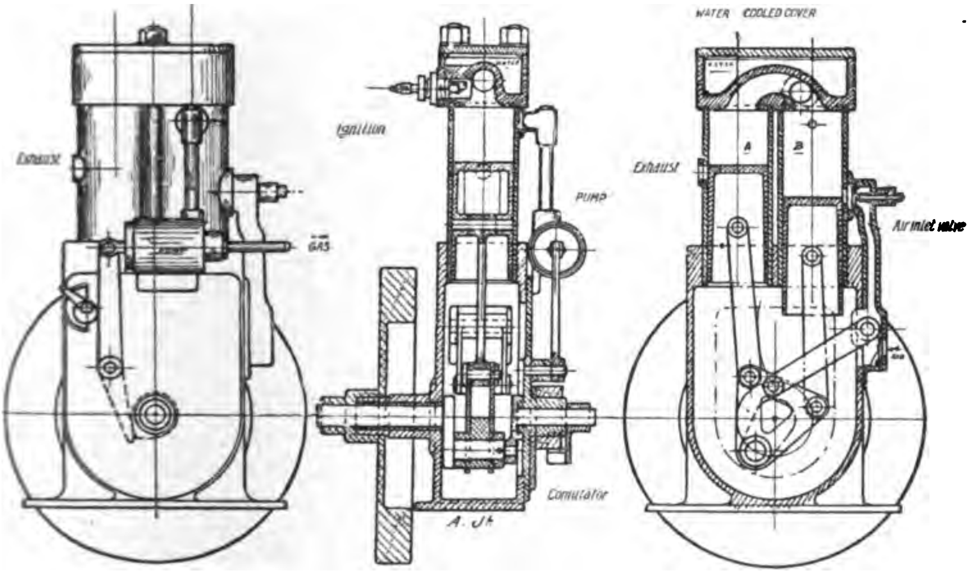
Motors working on the two-stroke-cycle will now be considered.

The Lister two-stroke-cycle motor is shown in elevation by Fig. 282, and in vertical section by Figs. 283 and 284; it obviously is a departure in motor design. The two vertical cylinders are used as cylinders, not one as a compression pump as in many two-stroke-cycle motors, and the two are connected by the passage in the water-jacketed head. Figs. 285 to 287 show diagrammatically the operations of the pistons and their connections. The two connecting rods R¹ and R² do not pass direct to the crankshaft, but are pivoted to the two upper angles of a triangular framework, whose remaining angle carries a bearing riding on the crank pin C. A swinging link, L, pivoted to the upper member of the triangle, is connected to a fixed point in the crank chamber.



Figs. 280 and 281.—Humber Bicycle Motor.

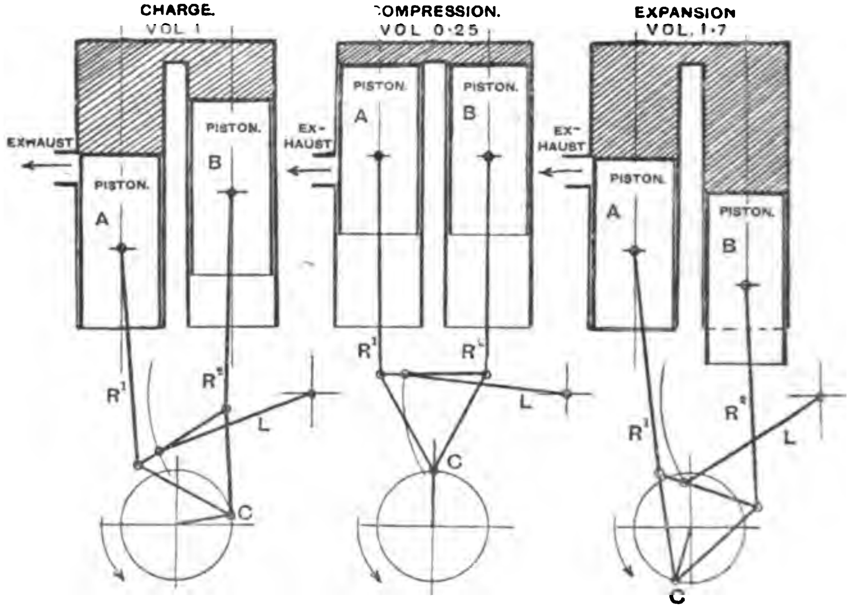
This method of linking causes the pistons to travel in a curious manner, relatively to the constant rotation of the crank-shaft, the result being that they assume the various positions shown in Figs. 285 to 287, when the crank pin C is at the three positions indicated. The upward movements of the two pistons draw air into the air-tight crank chamber, and when the pistons descend this air is forced up into the combustion chambers through non-return valves in the side of the crank chamber and in the cylinder B. Older two-stroke-cycle motors draw the actual charge into the crank chamber, an explosion in which would be very destructive. The pump, illustrated, is operated by a cam on the crank-shaft, and injects the actual fuel into the cylinder B, the carburation of the air already there being accomplished momentarily. The exhaust port in cylinder A is uncovered by the working piston; and in a general way both inlet and exhaust passages bear the same relationship to the two pistons A B as these passages usually do to the single piston employed; but, as is made clear below, the two ports are not open at the same periods of the cycle. The sections, Figs. 283 and 284, show that the incoming



Figs. 282 to 284.—Elevation and Vertical Sections of Lister Two-stroke-cycle Motor.

gases can pass to the exhaust port only after having scoured the cylinder B, and after having passed through the passage in the head of the cylinders.

The operation of the Lister motor is as follows: Each downward stroke of the two pistons is a working stroke because an explosion is occurring in their common combustion chamber; at the same time, the air in the enclosed crank chamber is being compressed. Directly piston A uncovers the exhaust port, the exhaust gases are free to escape; already the piston B has uncovered the air inlet port, but the non-return valve prevents the burning or exhaust gases passing to the crank chamber whilst the cylinder pressure exceeds that in the crank chamber. As the pressure is relieved, the air is forced into the combustion chamber; piston B begins its upward stroke first and scavenges the combustion chamber; then piston A, during its upward stroke, covers the exhaust port, and at this moment the spirit is injected into the air in the chamber so as to form an explosive charge. The pistons then complete their upward strokes, at the same time drawing



Figs. 285 to 287.—Diagrams of Operations in Lister Motor.

fresh air into the crank chamber. With regard to the relative movements of the two pistons, Fig. 285 shows their positions prior to compression, Fig. 287 at the end of the working stroke, and Fig. 286 the positions during the intermediate compression. The respective capacities of, or volumes contained in, the combustion chamber may be represented by 1 (Fig. 285), 1·7 (Fig. 287), and 0·25 (Fig. 286). The difference between the volumes 1 and 1·7 represents the amount of air forced through the combustion chamber out of the exhaust pipe, and also the greater degree of expansion in this motor than in a four-stroke-cycle motor. The diagrams show that piston B travels downwards faster than piston A, and that when B is about at the end of the down stroke, A uncovers the exhaust port; during the first part of the return stroke, the piston A opens and closes this port, and, travelling upwards faster than B, completes the stroke at the same time. With regard to the number of moving parts in the connecting rod link-work, F. Lister, the inventor, says that this compares favourably with the number of parts in a two-cylinder double-crank four-stroke-cycle motor, and this is a fair comparison. It may be feared that the method of injecting the fuel, and the peculiar internal construction do not favour very thorough carburation of the air already in the combustion chamber; and so, in the Lister small high-speed motors, this method is superseded by carburetting the air in the pump, whose delivery to the combustion chamber is under the control of an automatic governor, or can be adjusted by hand whilst the motor is running.

The Gobron two-stroke-cycle motor has a peculiar arrangement of the cylinder relatively to the crank shaft, as shown by the section, Fig. 288. The combustion chamber, *a*, has an electric ignition plug at the end farthest from the piston, and has free exhaust ports (not shown) at a point which is uncovered by the piston at the end of its working stroke. The piston has a hollow boss, *e*, on its upper face, and the boss is connected with a passage, *g*. The cylinder is air cooled, and is so constructed and attached to the closed crank chamber that the under side of the piston may act as a pump for drawing the explosive mixture from the pipe *c* into the crank chamber, and for forcing this mixture through the passage *d*, and port *u*, into the combustion chamber when the piston is in the position shown by Fig. 288. The axis of the cylinder is tangential to the crank shaft in order that the working stroke may be more rapid than the compression stroke, the inventor's object being to reduce the amount of negative work done by the fly-wheel. The crank chamber *b* contains two fly-wheels *j*, with the crank pin *k* between them. The connecting rod *h* is fitted in the usual way, but carries the bent strip of metal *s*, which at each revolution dips into and splashes up the oil contained in the chamber *l*. The action of the engine is very similar to that of other two-stroke-cycle motors. The piston is driven downwards by the explosion in the chamber *a*, and it then compresses a fresh mixture in the crank chamber; at nearly the end of a forward stroke the piston first uncovers the exhaust port and then opens free communication between the crank chamber and the combustion chamber, through the passages *d*, *u*, and *g*. The mixture is thus caused to take the place of the products of combustion, and the piston on the return stroke (it goes as far as the dotted outline f^1) compresses this charge in *a*, and also draws a fresh charge from a carburetter through the passage *c* into the crank chamber. This fresh charge enters by means of the hollow boss *e*, which enables the remaining products of combustion to be driven from the cylinder and reduces the tendency for the incoming charge to pass out through the exhaust ports.

The Goret six-stroke-cycle motor (Figs. 289 and 290) may be mentioned. The fifth and sixth period of the cycle, as is explained on p. 157, produce, after each explosion, a flush of pure air, which completely expels the burnt gases, and cools the cylinders. The three radiating cylinders have their pistons on the same crank. The regulation is by a needle valve varying the intake of petrol spirit into the carburetter, which totally atomises the amount admitted. There is electric ignition. As usual, the inlet valve is automatic. Each cylinder has a cam *a*, working a rod *b*, which lifts the exhaust valve placed at the side. The distributing cam *a* has a groove with special profile, with a small roller running in it, attached to the frame, and this works the distributing rod *b* with several side contacts. At the extremity of this rod there is a conical ring, which, by means of a roller, works the valve of an atomiser. Thus atomising is not constant, but is simply and mechanically produced for each cylinder every three revolutions (six phases) of the motor axle.

A compound petrol motor is the invention of Graham and Fox, of New York, and in this motor an attempt is made to utilise the exhaust gases in an auxiliary low-pressure cylinder. The idea is not new, but it has been supposed that the resultant gain of power would hardly compensate for the extra friction and trouble, and for the extra cost involved; however, the makers of the Graham-Fox advance figures showing that the power gain is far greater than could be expected, and even if these must be

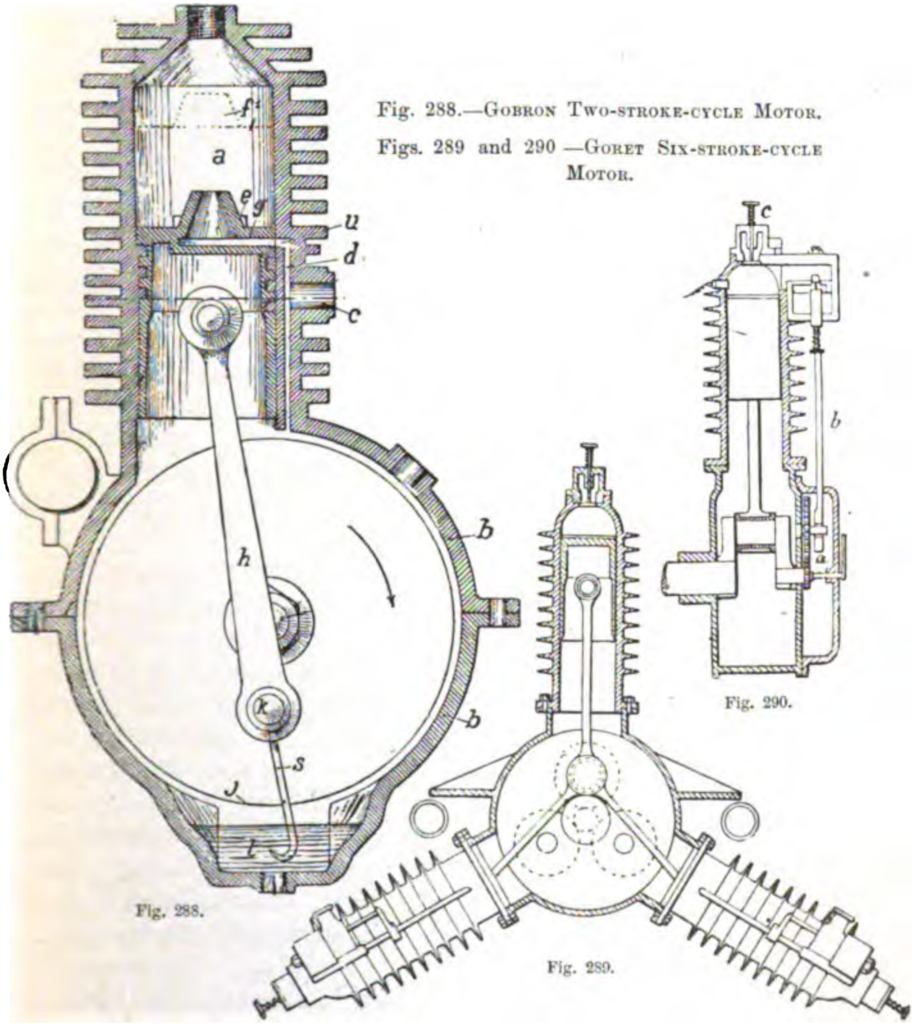


Fig. 288.—Gobron Two-stroke-cycle Motor.

Figs. 289 and 290.—Goret Six-stroke-cycle Motor.

Fig. 288.

Fig. 289.

Fig. 290.

largely discounted until confirmed or disproved by authoritative tests, they show that the motor is worthy of attention. Briefly, it consists of three cylinders cast together, of which the two outer ones are water-jacketed and work on the usual four-stroke-cycle, their bore and piston stroke being 127 mm. (5 in.). The middle cylinder is not jacketed, its bore is 190·5 mm. (7·5 in.) and its stroke the same as the others. The outer cylinders have pistons connected to cranks in line with each other, the piston of the middle cylinder working a crank opposite the others, so that as the outer and smaller pistons descend, the inner and larger piston ascends. Special valve gear allows the exhaust of the two outer cylinders to pass into the middle one, where the gases expand and do useful work. With identical fuel consumptions, this motor is said to have given 13·1 brake h.p. and 8·9 h.p. respectively with and without the low-pressure cylinder in use. It will appear from these figures, which must be accepted with great reserve, that the low-pressure cylinder, using the exhaust of two cylinders, has about the same power output as either of the high-pressure ones. However, the large bore and piston stroke being considered, the total output is not very astonishing.

In the James F. Duryea motor the combustion was produced in a special tank, which acted somewhat as does the boiler of a steam engine. The petrol spirit entered by a small tube into a large one, where it was vaporised under the action of heat from a lamp. The vapour passed through a cylindrical nozzle at considerable velocity, and carried with it the requisite amount of air to the combustion tank, where the combustion caused a pressure of about 8·5 kg. per cm.^{2} (121 lb. per sq. in.). A pipe ran from the explosion tank to the petrol spirit reservoir, so that in spite of the pressure in the tank the petrol spirit continued to descend. The intake of petrol spirit could be varied by aid of a valve on the feed-pipe. The double-acting effect obtained would have great advantages, but it is doubtful if this motor is in actual use on a car.

The Diesel motor has not yet been adapted, it is thought, to automobiles, but as it is based upon principles new to automobilism, and as it would be a desirable type for use on automobiles, a description of it may prove welcome (*see* also p. 153). In all combustion the temperature to which the fuel must be brought in presence of air before ignition is possible must be distinguished from the temperature produced during the chemical action of combustion. The temperature of combustion, strictly so called, always is attained after ignition by and during the combustion itself. Diesel maintains that in a motor the temperature of combustion should be produced before and independently of combustion, consequently before ignition, and solely by a mechanical heating of pure air. This condition is a simple consequence of the principles upon which the Carnot cycle is based. Not less than from 100 to 200 atmospheres are needed to produce this temperature of combustion by simple compression in the strict application of the four-phase cycle, that is, first by compressing air at two or four atmospheres following an isotherm, and then to a pressure corresponding to the required temperature following an adiabatic. If, on the contrary, compression following an adiabatic is produced from the outset a pressure of from 30 to 50 atmospheres suffices. Other theories are advanced in connection with Diesel's idea, but for the present purpose these can be dispensed with. A motor, based on quite novel principles, was designed by Diesel. Two combustion cylinders C (Fig. 291), with plunger pistons P, are connected by valves *b* with an intermediary cylinder B of greater diameter with piston Q, and by valves *a*, with an air-chamber L. The piston cranks P are parallel, and at 180° from that of the piston Q. The latter, through the valve

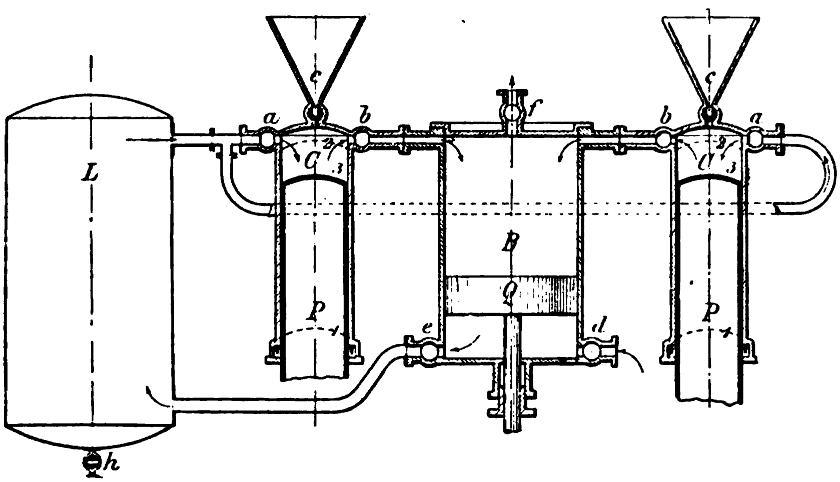


Fig. 291.—Principle of Diesel Compound Motor.

d, sucks air; the piston as it descends compresses the air in cylinder B to several atmospheres, and drives it through the valve *e* into the air-chamber L. The piston P, in descending to position 1 sucks air from this chamber, and in ascending to position 2 brings it to the final pressure. While descending to position 3, the pulverised carbon in funnel *c* falls into the cylinder C, where it burns. The gases of combustion expand and drive the piston to its lowest position 1. At this instant valve *b* opens, whilst P ascends, and the gases continuing to expand fill cylinder B above piston Q, which descends; this is the working stroke. When Q is on the point of ascending, *b* shuts, and *f* opens to allow the waste gases to escape. Thus the cycle of each cylinder C comprises four phases or two revolutions, the two together giving one driving stroke for each revolution. It would have been very complicated to construct at once the compound motor described, and at first there was a monocylindric engine fed with petroleum. The heavy compression, high temperature, and great speeds developed by this motor led to very great difficulties in construction of the various parts. In 1895 the experience gained in overcoming them was turned to account to build a second motor of 12 h.p., which gave remarkable results. At the end of 1896 was commenced the construction of a similar type of motor of 20 h.p., which was tested in the beginning of 1897. The 1895 motor was not provided with a water-jacket, but there are certain practical advantages with a system of cooling, especially the greater power obtainable, and this consideration led to its adoption in the 1897 motor to which petroleum was conveyed by a pump. This motor works quietly and reliably, having been tested carefully by Professors Schröter, Gutermuth, and Sauvage, and by French and German engineers, and the results appear to be so harmonious that they may be regarded as final. The indicated thermal efficiency was found to be equal to 34 or 35 per cent. with the normal charge, and to 38 or 40 per cent. at half charge. These figures are about 50 per cent. greater than the best results hitherto obtained for the indicated efficiency of gas motors which, according to Dugald Clerk, never exceeds 27 per cent., and very often is below this. The mechanical efficiency of the engine is between 71 and 75 per cent., that is to say, less than that of steam or internal combustion motors. The final efficiency, however, is not less than 26·6, which means that 26·6 per cent. of the heat of the fuel is transformed into effective work at the motor shaft The increase of this efficiency demonstrates the superiority of the new system over the old. The consumption of petroleum per brake horse-power hour was only 240 g. (8·46 oz.) for the full charge, and 277 g. (9·76 oz.) for half charge. Reckoning the petroleum at density 0·85, these weights are equivalent in volume to 0·28 l. (0·49 pt.) and 0·327 l. (0·575 pt.) respectively. The but slight difference between the two quantities demonstrates the small increase in expenditure of fuel due to a decrease of the charge. The thermal efficiency of the motor profits with the smaller charge, and so compensates for the relatively low mechanical efficiency. Compared with a motor of another type, for an equal number of revolutions the Diesel motor can give the ordinary power and be of smaller dimensions. As starting is accomplished by placing the air chamber and cylinder in communication, the motor is always ready to work, whether hot or cold, or whether it has been stopped for a few seconds or for several days. This would be an advantage in an automobile motor. Another advantage claimed for the Diesel motor is perfect combustion, there not being any fouling inside the cylinder and only odourless and almost invisible gases being expelled into the atmosphere, whilst the absence of carburetting and igniting devices allows a very simple construction.

The first Diesel oil motor produced in England was made by Scott and Hodgson, of Manchester, at the beginning of 1901, for the Diesel Engine Company, of London. It has important points of difference from previous Diesel motors made on the Continent, as it has but one horizontal cylinder, and works on the two-stroke-cycle. The horizontal arrangement is not considered an improvement, as the vertical position better suits the valves, piston, and other working parts; but the two-stroke-cycle is an advantage—for though in ordinary oil motors the chief objection to it is that some of the fuel escapes unburnt through the exhaust valves, or alternately in attempting to avoid this risk the charge is over-diluted with burnt gases—in the Diesel motor the scavenging charge is a mere air charge, the burnt gases are exhausted thoroughly, and the fuel gas is admitted to the cylinder only some time after the exhaust valve has closed. Ignoring its application to automobiles, it can be seen that for slow-speed stationary motors on the Diesel principle the two-stroke is better than the four-stroke-cycle. Figs. 292 and 293 are sketches explaining the action of the new motor. The working cylinder A has a bore of 20 cm. (7·875 in.), and the front of it is open to the atmosphere. A pump cylinder D, of 23 cm. (9 in.) bore, is placed in tandem with the working cylinder, and the two pistons B and C are connected together by a rod, which passes through a stuffing box in the end of cylinder D. The stroke of the pistons is 29·3 cm. (10·75 in.), and the clearance space behind the working piston when at its inmost positions is very small; the actual compression space is 5 per cent. of the total volume of the cylinder when the piston is at its forward dead centre. The air enters the working cylinder A through a port J, from a reservoir formed in the bed of the engine, and a non-return valve is provided in this passage. In this reservoir the air is kept at a suitable pressure, the supply being maintained by the pump cylinder D. Oil is pumped into an injection valve L, on the top of the cylinder A, the oil being driven by an eccentric on the cam shaft; this shaft lies parallel with the cylinders, and is driven in the usual manner, but at the same speed as the crank shaft. The cam shaft also operates a centrifugal governor and carries three cams, respectively the exhaust cam, oil admission cam, and starting cam. The oil pump has a bore of 9·5 mm. (·375 in.) and a stroke of 15·9 mm. (·625 in.), and has a constant which corresponds with that of the working piston, and its delivery pipe always is in communication with the injection valve L; its suction valve, however, normally is held open by a spring, but is closed at the beginning of the delivery stroke of the pump for a period depending on the speed of the engine. Thus the pump draws a full charge of oil at each suction stroke, but returns some, or even all, of this during the delivery stroke, only the balance being forced into the injection valve; the maximum proportion of oil delivered to the valve L is 10 to 12 per cent. of the capacity of the pump. The exhaust valve K is placed in the end of the working cylinder, and is operated in the usual manner by a cam; it is opened just before the end of the forward stroke, and is closed just before the piston B has covered the port J. The injection valve L also is operated by a cam, which opens it practically at the rear dead centre, and allows compressed air from storage cylinders to inject the oil into the working cylinder; this injection valve always closes at the same time—about 12 per cent. of the forward stroke. The working cylinder A is water-jacketed completely, and the pump cylinder D is water-jacketed round the under side. A water-jacketed high-pressure air pump E takes air from the pump cylinder D and delivers it under pressure to the storage cylinders in the bed of the motor, which are used for injecting the oil and for starting the motor. The air pump is driven by an overhanging crank-pin on the crank shaft, and the piston F reciprocates in the opposite directions to the larger pistons B and C; its cylinder has a diameter of 79·4 mm. (3·125 in.), and the stroke is 13 cm. (5·125 in.). The operation of the engine is as follows. The working piston receives an impulse during each forward stroke, at the end of which the

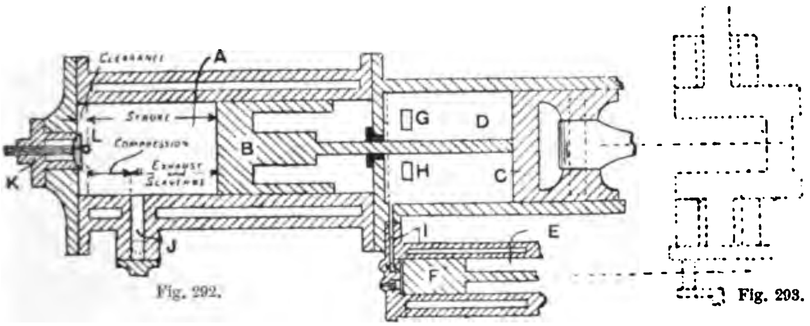


Fig. 292.

Fig. 293.

Figs. 292 and 293.—Diesel Two-stroke-cycle Petrol Motor.

exhaust valve K is opened. The products of combustion then pass out of the cylinder to the exhaust pipe, and as soon as the pressure in the cylinder is less than that in the air chamber in the bed of the motor air enters at J and scavenges the combustion chamber and fills it with pure air. The exhaust valve then is closed, and the piston covers the port J, after which the air charge is compressed to about 29·5 kg. per cm.^{2} (420 lb. per sq. in.). Next the oil admission valve is opened by its cam, admitting compressed air from the storage cylinders. The entering air injects such oil as is being delivered to the valve by the pump, and carries it in a diffused spray into the working cylinder. The low-pressure pump D draws its charge through a suction valve and through the port G. On the return stroke it delivers this air through a port, H, into the reservoir bed, and this delivery continues until the piston C has covered the ports G and H, when the remaining air is raised to a pressure of about 2·8 kg. per cm.^{2} (40 lb. per sq. in.), and passes only into the high-pressure pump cylinder E; this latter compresses its charge into the storage cylinders. For starting the motor a separate cam is caused to act upon the valve L, and to allow the stored high-pressure air to enter behind the working piston B. The valve opens at the beginning of the forward stroke, and it cuts off the admission at one-third of the stroke. This air drives the piston forward, and escapes through the exhaust valve K at the end of the stroke; at the same time oil is prevented from being delivered to valve L. After about ten revolutions, fuel is supplied and the engine runs normally. The power of the motor is from 15 to 20 h.p. at a speed of from 215 to 240 revolutions per minute. Of course, there is a wide gulf between this stationary motor and one that would be suitable for automobile purposes, but the above detailed description, which is due to the *Automotor Journal*, shows that a great deal has been accomplished, and gives much promise for a really practical automobile motor on the Diesel system.

The causes of petrol motors working unsatisfactorily may be considered briefly. In a motor whose charge is ignited electrically stopping or bad travelling is most frequently attributable to (1) defective compression, (2) defective ignition, and (3) defective carburetting. Bad compression may be due to a leakage caused by a badly fitting sparking plug (the best joints are asbestos and copper or wire gauze), or by a loose valve (valves, especially exhaust valves, should be re-ground from time to time). Defective ignition usually is due to a faulty sparking plug. Defective carburetting easily is detected with the bubbling carburetter. A leakage in the pipe uniting the carburetter with the motor may spoil the composition of the mixture.

In a motor having tube ignition the main causes of defective working are failure of compression, which may totally prevent working of the motor, and, secondly, feeble ignition. It is desirable to be able to aid the combustion of the burner, which heats the tube by blowing in air with an indiarubber tube and ball. The method of carburetting, also, is to blame sometimes, and with the atomising carburetter usually employed when there is tube ignition it is rather difficult to find the weak point. Defective carburetting may be caused by an insufficient supply of petrol spirit (owing to the choking of the capillary tube), or by an excess (owing to the float not working); in the latter case dense smoke issues from the silencer. The governor may work faultily, and, to ascertain if this is the case, it must be disconnected to see how the motor works without it; take care to have slight carburetting, so that the motor does not race. It must be remembered that a new motor does not at first give the power for which it was built, because perhaps the cylinder is not perfectly reamed, the piston is too tight or is too small, or the segments have not yet properly fitted to the form of the cylinder. After a time these defects disappear.

The chief defect of the petrol motor is the one emphasised in Chapter IX., lack of elasticity. This makes it necessary, when a variable power is needed, to have on the motor several cylinders, the number of which, brought into action, is proportional to the power required; but it would be much better to give the motor the elasticity of which it is deficient, for which purpose it would be necessary to vary either the richness or the degree of compression of the mixture, and perhaps both. The variation in richness appears at first to be simply the work of the carburetter alone, but generally the carburetter acts only by suction of the piston, this suction decreasing with the speed of the motor when it meets greater resistance, that is to say, when the feeding of the carburetter should be accelerated. The distributor, based upon the idea of mechanically introducing a certain amount of petrol spirit, appears a more suitable device with which to accomplish the variation. The charge of petrol spirit can easily be operated by aid of a drop-counter tap whose seat, containing cavities filled with petrol spirit, is made to turn at a speed proportional to the required energy; but regulation of the air and its mixing with the petrol are difficult in this device. Perhaps the difficulty will be overcome by combining this device with electric ignition. It is to be hoped that the Diesel motor will be applied to automobiles.

Another inconvenience of petrol motors is the vibration caused in the cars, especially when at a standstill, and constructors rightly are endeavouring to balance the parts. The method of placing counter-weights on the heads of the connecting rods and at their junction with the motor shaft and pistons is simple, but balancing is only obtained for one speed. Balancing by inverse motion of conjugated pistons appears to be a better method;

though balancing by working two pistons in opposite directions by an explosion between them seems more perfect in theory. The petrol motor is still a new invention, and this fact gives hope that it will have important improvements. Carburetting, in particular, might be improved, and the governing of ignition made more exact. It would be well to consider carefully the influence on the power of the motor of the volume of the cylinder and the rate of compression. Efficiency will be improved by decreasing the losses of heat caused by cooling the cylinders, these losses amounting sometimes to 30 per cent. of the heat units developed by the combustion. If a lubricant is found which does not decompose at 350° or 400° C., the decomposing point of the oleonaphthas hitherto employed, the cylinders can be allowed to get hotter, and so much will be gained. The aim must be some more methodical cooling, either by aid of automatic valves regulating the current of water according to the temperature of the cylinder, or by the aid of a fan driven by the motor and sending a variable amount of air between the cylinder flanges (Diligeon system).

A practical rotary petrol motor is very desirable, and would most certainly lessen vibration and wear, but its invention seems to be more remote than that of a rotary steam motor for automobile use. It is true that a large number of designs has been introduced (*see* pages 201 to 206 of the first edition of this work), but not one of them has given satisfaction, and so far as is known, there is not a single example in actual employment on an automobile. The André Beetz, Dodement, Vernet, Gardner-Sanderson, and Chaudun rotary motors are just a few of the many inventions in this direction.

CHAPTER VIII.

ACCUMULATORS AND ELECTRIC MOTORS FOR AUTOMOBILES.

The accumulator is the only source of electrical energy of practical use for driving an automobile, because an electrically propelled car, like other automobiles, must self-contain its supply of energy, and thus it excludes employment of the trolley running under a conductor in constant communication with generators at the power station; it is the trolley system of electric traction that experience has indicated as being most practical. True, it has been proposed for automobiles, but it is well-nigh impossible for cars that have to run under ordinary road conditions, though one or two services of omnibuses are being so propelled. Whilst electricity has become one of the most powerful agents of transport, still almost exclusively the system that is employed is the one using an overhead or underground conductor; for the few tramcars with accumulators which have been run have not proved economical generally.

The overhead or underground conductor being excluded there remain only primary or secondary batteries available for the automobile. Primary batteries, as their name indicates, directly transform chemical energy into electric energy, and, therefore, might be expected to supply electricity very cheaply; but such is not the case, because the materials—acids, salts, zinc (the attempts made to replace this metal by other substances have mostly proved fruitless) consumed by the battery are more expensive than coal, from which indirectly the dynamo obtains its energy. Hospitalier, an enthusiastic and judicious advocate of the electric automobile, reckons that a bichromate of potash battery consuming the material strictly necessary for the production of 1 kilowatt-hour, say 1 kg. of amalgamated zinc at 7½d. per kg. (2·2 lb. at 3½d. per lb.), and 1·668 kg. of bichromate of potash at 11½d. per kg. (3·7 lb. at 5¼d. per lb.), costs 2s. 2½d.: including sulphuric acid the cost is 2s. 4½d. If it is assumed that an electric car must carry a supply of energy of from 5 to 10 kilowatt-hours, according to the weight of the car and the length of the journey, the chemical products alone would cost from 15 fr. to 30 fr. (11s. 10½d. to 23s. 9½d.). The battery is not only costly, but is also very heavy, owing to the necessity of diluting the acid and dissolving the potash in a large amount of water, all being carried in heavy vessels. Again, its E.M.F. does not exceed 2 volts, and 0·2 volt may be absorbed by internal resistance. Thus it results that the specific power (quotient of its useful power divided by its weight) is only 1 to 2 watts per kg. and its specific energy does not exceed 4 to 5 watt-hours per kg. (1·8 to 2·27 per lb.). It need hardly be remarked that for traction purposes the electric generator should possess great specific power, so as to be able at a given moment—as at starting, ascending a steep gradient, etc.—to develop a considerable power, and great specific energy to be able with slight weight to propel the car for a sufficient length of time. Employment of primary batteries, then, is inadmissible.

As regards accumulators, that is, secondary batteries, some years ago they were not any more practical than primary batteries, for in 1881 the Faure type hardly gave as power and energy 1 watt and 7 watt-hours per kg. (2·2 lb.) of total weight, which is much the same as that given by the primary battery. However, the Fulmen type actually yields a specific power of 8 to 10 watts and a specific energy of 20 to 30 watt-hours per kg. Progressing in the same direction, the 2 to 3 kilowatt electric motor, which in 1881 weighed from 30 kg. to 40 kg. (66 lb. to 88 lb.), with an efficiency of only 60 per cent., weighed in 1897 from 15 kg. to 20 kg. (33 lb. to 44 lb.) per kilowatt, and its efficiency was 85 or 90 per cent. This advance rendered possible the adoption of electricity for automobiles, as was proved by the Paris cab trials of 1898, 1899, and 1902.

The storage batteries or accumulators used in electric automobiles are adaptations of the storage batteries used for electric lighting, but are much lighter and give a greater output, weight for weight; they are also made to bear over-discharge, and the wear and tear of rough travelling. The active agents in general use are lead and dilute sulphuric acid. The storage batteries may be divided broadly into two classes; namely, the "to-be-formed," or Planté kind (1873); and the "pasted," or formed Faure kind (1881). The object of both processes is to produce a couple consisting of a positive electrode of lead oxide, and a negative electrode of lead in a solution of sulphuric acid and water. Peroxide of lead is formed on the positive, and pure lead on the negative, by the process of charging; and energy is stored which is given up on discharging the battery, when the electrodes return to their first state of lead sulphate. The pasted cell is lighter than the other, and is more generally used in electric automobiles.

Accumulators have been adapted for automobile use in a number of ways that have been summarised by Mr. H. F. Joel. The mechanical details of the supporting grids have been modified to allow full expansion of the paste and to avoid sulphating; the specific gravity of the electrolyte has been increased from between 1·05 and 1·20 to between 1·15 and 1·30, with consequent decrease of volume and weight, and increase of output; the active material, the paste, has been improved in chemical composition, and also has been mixed with inert materials in order to make it more coherent and porous. As a result, automobile batteries give, weight for weight, three to four times the output of batteries used for electric lighting. The use of zinc with peroxide of lead gives a higher electromotive force (according to Wheatstone 2·446 volts) than lead and lead peroxide, but necessitates the use of porous pots. Such a battery has the advantage that it can be quickly charged, and the whole energy can be stored in 1 or 2 hours. A zinc and peroxide of lead battery of 120 ampère-hours can be charged at 90 ampères for 2 hours, and discharged at 20 ampères to 100 ampères.

Every battery which does not give an appreciable quantity of volatile products can constitute, theoretically, an electric accumulator, but as yet good results have been obtained with the three following combinations only:—(*a*) Lead-and-lead accumulator, with sulphuric acid and water; (*b*) Lead-and-zinc accumulator, with sulphuric acid and water; and (*c*) Zinc and copper accumulator, with potash or caustic soda solution. The last gives only a small E.M.F., 0·8 volt per cell. The second would give a considerable E.M.F., say 2·4 volts, and its zinc negative plates would be much lighter than lead plates; but the difficulties in charging have been regarded up to the present time as prohibitory. However, Riker, of Brooklyn, employs accumulators of lead and zinc, some details of which are given when mentioning his cars (*see* p. 724), and the possibility of employing a lighter substance than lead, and capable of forming a powerful and efficient accumulator, is not despaired of. Pisca does not doubt the ultimate issue: "The theory is formed," he says, "we must compel the substances selected to follow the path hidden by the difficulties of execution but indicated by calculation." Edison has raised hopes—probably vain ones—of a lighter and more powerful accumulator (*see* p. 313).

The lead-and-lead accumulator for traction consists of spongy lead negative plates and of peroxidised lead positive plates dipping into dilute sulphuric acid. The difficulty is to obtain a sufficient adhesion between the active material and its support to resist variations of volume and cohesion inseparable from periodical transformations upon which the working of the accumulator depends. Usually the support consists of grids in which pellets of the active material are placed. Sometimes, as in the Phœbus accumulator, the material is placed between two inter-crossing gratings, in which case it forms a continuous piece. In accumulators intended for traction, the difficulty of getting sufficient adhesion is aggravated by the necessity of reducing the weight of the supporting grid as much as possible in order to increase specific power and energy; also, the vibrations tend to detach the active material. When the latter is formed without pasting, the cell is of the Planté type. The method is little employed, on account of the long time taken to form the battery. In nearly every case the mechanically deposited pasted formation is employed. This type, invented by Faure, adapts itself to the most varied forms of the grids, which secure the pellets of active material. To obtain in this type a considerable specific discharge and capacity very thick plates must be avoided, as also excessively wide sockets, which would not give the active material sufficient contact with the support and electrolyte. It may then be concluded with Hospitalier that, until further developments, traction accumulators will be all or nearly all lead-and-lead accumulators (ordinary soft lead for negative plates and antimony-lead for positive) of Faure formation, and mechanically applied oxides. Certain accumulators are seen with positives of the Planté formation. Wallace Jones considers that this mixed system will supersede others. Wythe Smith goes further, and considers that perhaps the Planté element, more or less modified, will have to be adopted. Connection between the various plates is made by cross-pieces of the same metal, or alloy, as the plates themselves, that is, of soft-lead and antimony-lead. The cross-pieces are fastened by screwed bolts and nuts of antimony-lead, if it is wished to be able to take the elements apart.

To prevent contact between the positive and negative plates, round indiarubber rings, 5 mm. to 8 mm. (0·2 in. to 0·3 in.) in diameter, are placed at the edges of the plates; they are vertical, so as not to facilitate short circuits by arresting detached particles of the active material. For traction accumulators very thin sheets of ebonite or of celluloid are often employed perforated with holes from 1 mm. to 2 mm. (0·04 in. to 0·08 in.) in diameter, the total area being equal to at least one-third the area of the sheets. Thus the resistance to the current is negligible, and the sheets are perfect safeguards against short circuits. Although a strong solution of sulphuric acid is not very favourable to preservation of the electrodes, Hospitalier does not hesitate to recommend it for this type; a density of 1·32 (35° Baume) seems to him necessary to obtain a sufficient E.M.F. discharge and to reduce the weight carried. It is also for this last reason that the receptacles are made as light as possible; celluloid, which is being abandoned, would be the ideal material were it not so inflammable; in fact, it has caused several fires. Ebonite is now used; perhaps some day it will be possible to employ ambroine, pegamoid, canvas lacquered hot under pressure, or compressed cardboard coated with indiarubber or lacquered. The lid must be sealed to prevent spilling of the liquid during the journey, but a small hole is made in it to allow the gases to escape during the charge. Dimensions of the grids may vary much, but their number remains constant at about 40 or 44, owing to the advantage there is in being able, when charging them, to place them on the ordinary supply circuits at 110 volts and for changes of speed to divide them into four equal batteries. Some constructors, like Bouquet, Garcin and Schivre, and Patin, employ special accumulators, regarding which they give hardly any details. Most makers employ ordinary commercial types which there has not been time to adapt to their new service. In addition to those about to be described, those of Gadot, Faure-King, and Bristol may be mentioned.

The Lamina accumulator of the Planté type (Fig. 294) was employed by Elieson. Each of its plates is formed by a number of sheets of lead perforated and corrugated horizontally and vertically alternately. This shape gives the plates great surface and free circulation to the acid. The plates are enclosed in a perforated lead casing, which, says the inventor, maintains the active material very well. It is stated that the accumulator can be short-circuited without any deterioration, and this last advantage is valuable if it exists. The type 17·5 cm. (6·9 in.) long, 10 cm. (3·94 in.) thick, and 32·5 cm. (12·8 in.) high, having a quantity capacity of 100 ampère-hours with a discharging current of 20 ampères, and 120 ampère-hours with 10 ampères, weighs 12·23 kg. (27 lb.). A battery of forty cells giving 8 available kilowatt-hours weighs 500 kg. (1,100 lb.). Thus the weight of battery per kilowatt-hour is 62 kg. (136·4 lb.) with a discharge of from 3 to 3·5 watts per kg. (1·36 to 1·59 watts per lb).

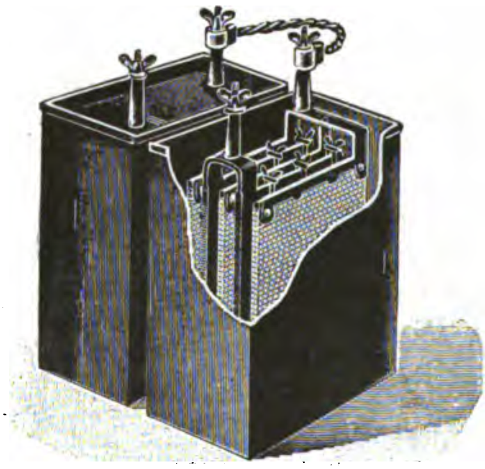


Fig. 294.—Lamina Accumulator.

The Elieson-Bobinsky accumulator is a new type with plates composed of lead in thin ribbons, one ribbon being straight and the next corrugated. They are packed side by side, and offer a large surface to the electrolyte. The cell, with two positives and three negatives, weighs 10 kg. (22 lb.) complete, and gives 100 ampère-hours on a five-hour discharge rate.

The Fulmen accumulator is by far the most commonly employed up to the present time, at least by French constructors. Figs. 295 and 296, reproduced from a photograph, show the two parts of a plate, and Fig. 297 its aspect when assembled. The very light grids are of cast antimony-lead. In the type illustrated they are divided by transversal and longitudinal bars into thirty compartments, each subdivided into a dozen small cells. One of the frames has round dowels or pins, corresponding to openings cast in the other, into which they enter when the plates are paired. The sides of the frame slant inwards, and all the inner bars are triangular in section, having one angle likewise inwards, so that the hollows formed between these frames are dovetails in which the inlaid oxide is held fast. At the same time as the active material is being suitably compressed the pins of one frame are forced into the holes in the other, and, thus firmly secured, the plate contains, set in its squares, 360 pellets. The plates thus formed are placed in ebonite cases, and rest on cross-pieces also of ebonite. The ebonite lid has an opening for filling, and for the passage of the connecting strips, the hole being closed by a plug and pure india-rubber washers. Hospitalier, who tested this accumulator in his laboratory, supplies the following particulars:—The cell (B 13) which he more especially studied contains 13 plates. An element always has an odd number of plates in order to enclose the positives by negatives; without this precaution the positives, being unequally attacked, would be warped. The plates are 18·5 cm. (7·3 in.) high, 9·5 cm. (3·7 in.) wide, and 4 mm. (0·16 in.) thick, forming a checker of 24 rectangular pockets. With these separate plates, and the celluloid case, it weighed 7·5 kg. (16·5 lb.). With ebonite, which is now exclusively employed for making the boxes instead of celluloid, owing to the inflammability of the latter, there is an increase in weight of 3 per cent. During 5 hours it supplies

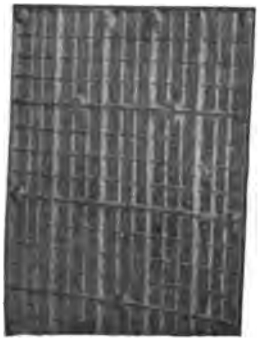


Fig. 295.

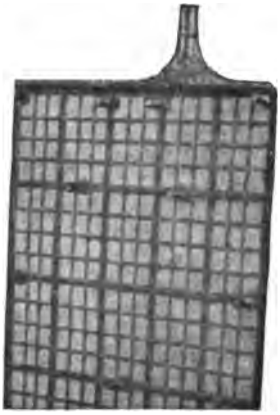


Fig. 296.

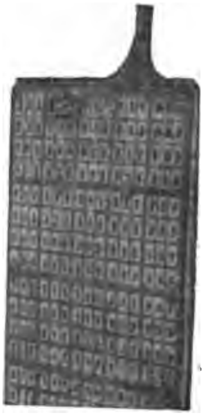


Fig. 297.

Figs. 295 and 296.—Parts of Fulmen Accumulator Plate. Fig. 297.—Fulmen Accumulator Plate Complete.

normally a current of 21 ampères—that is, 1 ampère per dm.^{2} of surface in the positive plate; moreover, it can give, with reduction in its capacity, up to 50 ampères in continuous discharge, and 100 ampères for an instant. At the normal discharge in 5 hours, the E.M.F. of a single cell is 1·9 volts on the average; the capacity is 105 ampère hours, and the power 21 ampères × 1·9 volts, equals 40 watts; the available energy is 200 watt-hours. If these various figures are divided by the weight 7·5 kg. (16·5 lb.) of the element, most of the specific constants given in the second column of the following table are obtained.

PARTICULARS OF ACCUMULATOR.	Fulmen.	Faure-Sellon-Volckmar.	Pulvis.	Société Anonyme pour le Travail des Métaux.	Bouquet, Garcin and Schivre.	Phœbus.	Pisca.
Number of plates in ordinary cell	13	23	7	13	15	13	13
Specific discharge in ampères per kg.	3	1·6	1·87	2·17	3	2	2·2
Specific useful power in watts per kg.	5·3	3	3·65	4·1	5·3	3·7	4·2
Specific capacity in ampère-hours per kg.	14·6	8	9·37	7·76	21	9·9	6·6
Specific useful energy in watt-hours per kg.	26	15	18·25	14·7	27·6	18·5	12·6
Specific weight in kg. per kilo-watt-hour	37·5	65	54·6	68	36·2	54	79·2

It must not be forgotten, when fixing the specific constants of the battery to be used, that the more moderate their rates of discharge the longer do they last.

The Faure-Sellon-Volckmar accumulator made by Valls and Co. has pure lead negative plates with very small pockets (Fig. 298). The positive plates (Fig. 299), also of pure lead (the use of soft lead compensates for the gradual fall of the active material), have a rather thick core upon which are horizontal and vertical grooves arranged to prevent loss of the general rigidity. A thin sheet of perforated ebonite placed on the plates prevents the fall of the active material, and another corrugated plate assures insulation. The ebonite cases are shut or simply covered with a plate of the same substance to prevent the liquid being spilled

The normal cell has 23 square plates, each 14·5 cm. (5·7 in.) wide, and weighs 15·95 kg. (35 lb.). The light and extra light cells have respectively 19 and 13 plates, and weigh 11·4 kg. (25 lb.) and 8 kg. (17·6 lb.). It gives a current of 35 ampères for 5 hours, that is, 0·54 ampères per dm.^{2} of positive surface; the E.M.F. averages 1·9 volts; capacity, 135 ampère-hours; power, 48 watts; available energy, 240 watt-hours. The specific constants are given in the table on p. 306.

In the Pulvis accumulator the positive plates are of lead about 9 mm. (0·35 in.) thick, and on both the surfaces there are horizontal grooves very close together which are filled with impalpable lead powder. The negatives are similar to the positives, only the plates are thinner and they have horizontal ribs at intervals of 4 mm. to 5 mm. (0·16 in. to 0·2 in.), with a dovetail profile to better retain the active material. The ends of the connections are soldered to a cylindrical lead bar which has a copper core. The plates rest on two ambroine prisms, intended to form a free space between the plates and the bottom of the boxes, which are also of ebonite; they are separated by sheets of ebonite, corrugated and perforated. The cell T 7 is composed of 7 plates, 15 cm. × 19 cm. (5·9 in. × 7·5 in.), and weighs 16 kg. (35·2 lb.). It gives a current of 30 ampères for 5 hours, say 0·156 ampères per dm.^{2} of working positive surface; the working E.M.F.

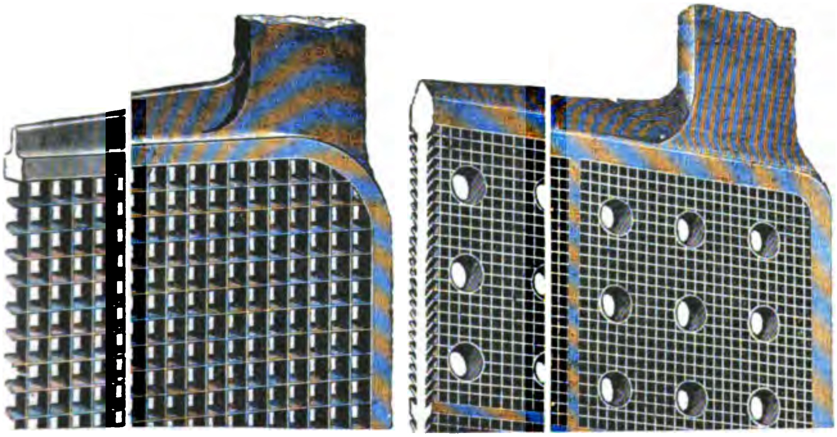


Fig. 298 and 299.—Faure-Sellon-Volckmar Negative and Positive Plates.

is 1·95 volts; capacity, 150 ampère-hours; power, 30 ampères × 1·95 volts, equals 58·5 watts; available energy, 202 watt-hours.

The accumulator of the Société Anonyme pour le Travail Electrique des Métaux has the negative plates, based on the Faure type, formed by a lead grid serving as support to spongy lead pellets obtained by reducing lead chloride. The positive plates, of the Planté type, are formed by corrugated bands of lead superposed and united with each other by a special process. The cells actually employed for the cabs of the Paris Compagnie Générale des Voitures consisted of 13 plates, each measuring 210 mm. × 110 mm. (8·26 in. × 4·3 in.), resting on an ebonite support and separated by corrugated and perforated ebonite plates; they were enclosed in ebonite cases and weighed 17 kg. (37·4 lb.). They normally gave a current of 37·7 ampères for 3½ hours, say 1·3 ampères per $dm.^2$ of positive working surface; the useful E.M.F. was 1·9 volts; capacity, 132 ampère-hours; power, 71 watts; available energy, 250 watt-hours. Specific constants are given in the table on p. 306.

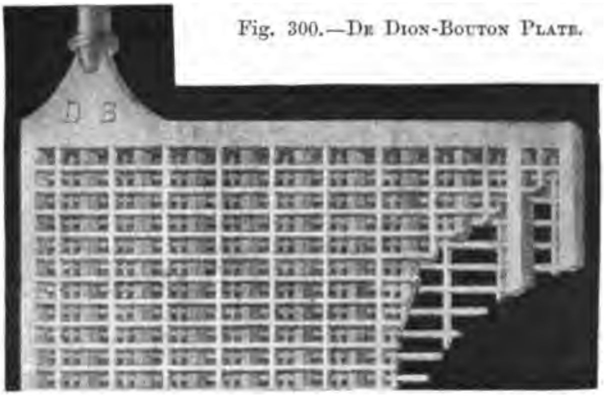


Fig. 300.—De Dion-Bouton Plate.

The Bouquet, Garcin and Schivre accumulator has no particular feature from the structural point of view. The inventors, however, claim for it an exceptional specific capacity (20 to 22 ampère-hours). On an automobile at the normal rate of discharge in six hours the battery of 15 plates would give one horse-power hour with a weight of about 126 kg. (277 lb.). A recent type has a greater specific efficiency and occupies less space.

The Phœbus accumulator constructed by Kaindler has its active material placed between two parallel grids made of antimony-lead, and strongly fastened together; this material thus forms one continuous mass instead of being in separate pellets. The ordinary cell comprises 13 plates, each 95 mm. (3·74 in.) wide, and 160 mm. (6·3 in.) high; it weighs 7·85 kg. (17·3 lb.), and normally is discharged in 8 hours (*see* the table on p. 306).

The Pisca accumulator is constructed with a view to lasting power rather than great specific capacity; the plates vary from 3 mm. to 4 mm. (0·12 in. to 0·16 in.) in thickness, the negative plates being a little thinner than the positive; their edges slide in the vertical grooves in two opposite sides of the ebonite case, which has a lid with double partition that prevents the acid from being spilled without ,impeding the escape of the gases. The normal discharge takes 3 hours; if it is effected in 1½ hours the capacity is only 92 per cent. of its normal value; if, on the contrary, it is extended over 6 hours the capacity is increased by 20 per cent. The average cell having 13 plates weighs 21 kg. (46 lb.) (*see* the table on p. 306).

The Blot-Fulmen accumulator is made of Blot positive shuttle plates of the Planté type and Fulmen negatives. These plates rest on supports placed on the bottom of the ebonite case, and are insulated by sheets of corrugated and perforated ebonite; the connections are made of antimony-lead. The positive plates, 8 mm. (0·315 in.) thick, weigh 560 g. (19·74 oz.); the negatives, 4 mm. (0·16 in.) thick, weigh 300 g. (10·6 oz.). Its capacity is twelve ampère-hours. The number of plates varies from 11 to 25; the element of 21 plates employed by Jenatzy for the delivery cart of the Magasins du Louvre, shown in 1899, weighs 25 kg. (55 lb.), and has capacities of 250, 230, 200 ampère-hours with respective discharges in 10, 5 and 3 hours.

The de Dion-Bouton new accumulator employed on the light electric car consists of 44 cells of 200 ampère hours' capacity. The large cell contains 21 plates, with ebonite separators between them, and the special form of grid used (Fig. 300) consists of a stout framework between two lighter frames or networks, whose meshes overlap each other. This grid is rigid, and holds the paste well, but presumably is expensive to manufacture. No particulars are obtainable with regard to the specific weight of this battery.

Figs. 301 and 302 are face view and enlarged section of the Rosenthal or National electrode; the supporting grid is covered entirely by the active material, of which there is a much larger amount in proportion to the lead conductor than in any other cell, according to H. F. Joel. In a cell (Fig. 303) these electrodes are held in position by vertical rubber bands, upon which the electrodes rest. A complete cell weighs 10·6 kg. (23·5 lb.), measures externally 16·2 cm. by 10·2 cm. by 25·4 cm. (6·375 in. by 4 in. by 10 in.), and its output is 180 ampère-hours, about 360 watt-hours. A group of eight complete cells (Fig. 304) arranged in a portable tray ready for use in a car weighs 91 kg. (200 lb.), measures 85 cm. by 21·6 cm. by 30·5 cm. (33·5 in. by 8·5 in. by 12 in. high), and its maximum output is 2,880 watt-hours, equal to 3·86 h.-p. hours, this being at the rate of 23·6 kg. (52 lb.) of battery per h.-p. hour.

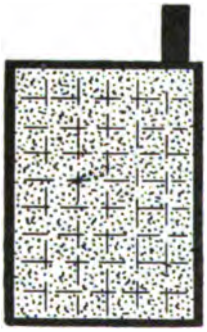


Fig. 301.

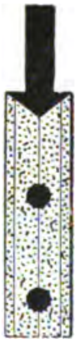


Fig. 302.

Figs. 301 and 302.—Rosenthal or National Accumulator Plate.

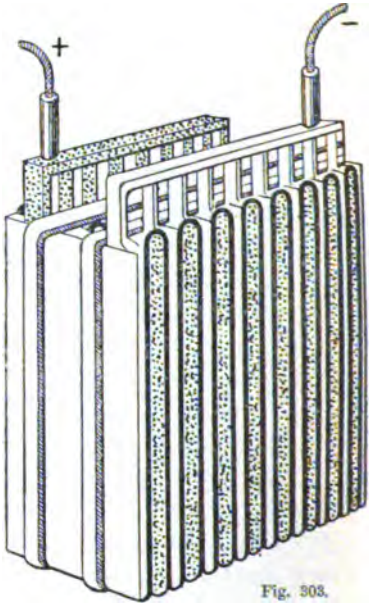


Fig. 303.

Fig. 303.—Rosenthal or National Accumulator Cell.

The Ideal accumulator is used on the Still electric vehicles; each cell, about 15·24 cm. by 12·7 cm. by 8·89 cm. (6 in. by 5 in. by 3·5 in.), contains four pairs of plates which are of the Faure type, each being of lead, pasted as usual. In the plates, strips are cut horizontally, these strips being twisted like the laths of a venetian blind. Three rubber bands keep each plate together and allow for expansion and contraction, and ebonite feet and forks are placed under and between the plates. The normal charging rate is 20 ampères for 3 hours, but in emergencies the full charge can be given in 1½ hours. The normal discharge is from 12 to 15 ampères, but on occasion from 40 to 50 ampères can be obtained without injuring the battery. A capacity of 22 watt-hours per kg. (10 watt-hours per lb.) of plate is claimed by the makers, and though this is not very high, the known long life of the Ideal cell is a compensation.

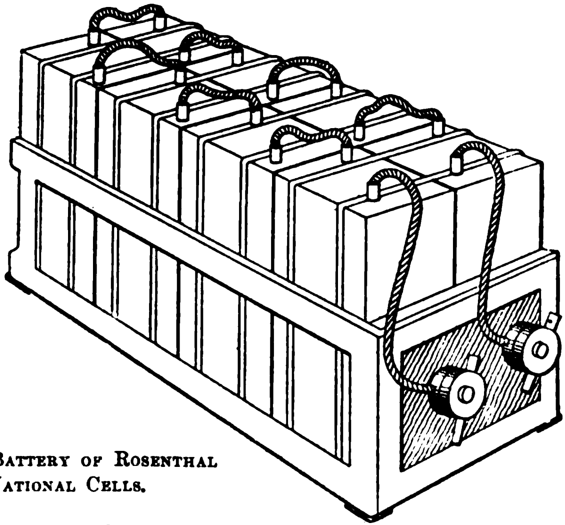


Fig. 304.—Battery of Rosenthal or National Cells.

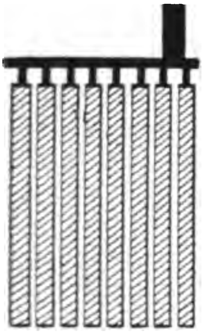


Fig. 304.

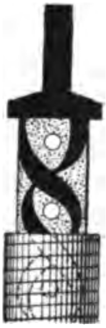


Fig. 305.

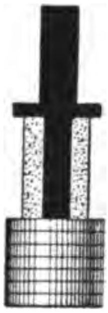


Fig. 306.

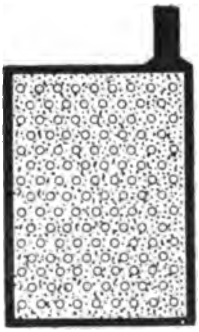


Fig. 307.

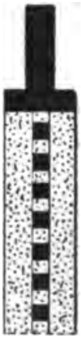


Fig. 308.

Figs. 304 and 305.—Pope Electrode. Fig. 306.—Phœnix Electrode.
Figs. 307 and 308.—Electrode used by Somzée, Leitner, etc.

The Pope (American) electrode (Fig. 304) is formed of a number of the cylinders shown in section by Fig. 305, the active material being pasted in the spirals of the central support, and being kept in place by spiral insulating tape or bands.

The electrode of the Phœnix accumulator (French) is a cylinder (Fig. 306) with the active material placed round a central rod and kept in position by a pile of ebonite discs which surround it.

An electrode formed with a central plate of thin sheet lead containing holes or slots, the active material entirely covering the conducting plate is shown in face view and enlarged section by Figs. 307 and 308; this has been used by Somzée, Joel and Eaton in 1882, and Crowdus, Leitner, and others in 1899.

The Hart accumulator for automobile use has a "lattice" type of negative, while the positive plate is an open latticework of cast lead (*see* Figs. 309 and 310), whose flat horizontal portions, A, are united by vertical conductors, B. The grid is rolled to turn up the projecting edges of the extending horizontal part, and so form a number of recesses which well hold the active material after pasting. The positive plates, before putting in position, are wrapped twice with a thin porous silicious cloth, which is said to be unacted upon by acid. Then they are secured by perforated ribbed separators. Three sizes, for discharging in 10 hours, have capacities of 80, 120, and 160 ampère hours respectively, their weights being 7·7 kg., 10·9 kg., and 15 kg. (17 lb., 24 lb., and 33 lb.). Thus the capacity is 19·8 watt hours per 1 kg. (9 watt hours per 1 lb.).

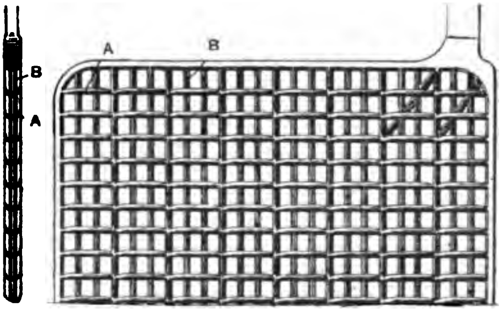


Fig. 309. Fig. 310.

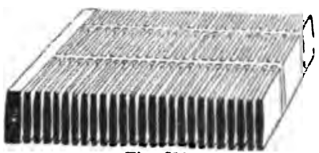


Fig. 311.

Figs. 309 and 310.—Hart Accumulator Plate.

Fig. 311.—Hagen Accumulator Plate.

The Oppermann accumulator has very thin open plates, all pasted, and the edges are angular. By means of rods of insulating material passing through two holes, one above the other in every plate, the whole section can be bolted up tight against the separators, which each consists of two thin sheets of perforated ebonite, held apart by vertical strips or ribs. The section is firm and rigid, and the paste cannot be dislodged. One cell contains 11 plates, weighing 9·54 kg. (21 lb.), and the total weight of the cell is 10·9 kg. (24 lb.), and is claimed to give 198 ampère hours; whilst owing to the high voltage of the discharge, at least 400 watt hours is the output. This works out at nearly 37·5 watt hours per 1 kg. (nearly 17 watt hours per 1 lb.), and it is said that these figures have been verified by Sir William Preece. On an Oppermann delivery van, built for the Post Office, there are 40 cells, having a total capacity of 160 ampère hours; these energise a 3-h.p. motor.

Hagen accumulators closely resemble the Tudor, and until recently had a positive plate with ribs forming projections; but now an "all through" type of plate (Fig. 311) is adopted, the ribs or laminations being connected only by vertical stays, and there being clear spaces between them. This is becoming general practice.

The Max accumulator has plates built up of lead wire rod, plated with antimony and covered with litharge and forming a pencil about 4·57 mm. (·18 in.) in diameter. The rods have woven asbestos covers, and are lead-burnt to form plates. The top of each plate connects the rods together and is of a zigzag pattern, and a zigzag ebonite separator, corresponding with it, is placed at both top and bottom, between every two plates; the asbestos serves as a separator elsewhere. The construction is made quite clear in Figs. 312 and 313.

In A. T. Edison's new accumulator much interest has been evinced since June, 1901, when Dr. Kennelly read a paper upon it at the American Institute of Electrical Engineers. The accumulator may very shortly be on the market, and until then it is not advisable to express any opinion as to its merits; however, the claim is set up that it will answer admirably for automobiles. It is a nickel-iron cell, the negative pole or positive element being of iron and corresponding to the zinc of a primary cell or the spongy element of a secondary cell, whilst the positive pole or negative element, corresponding to the carbon of a primary cell or lead peroxide of a secondary cell, is a superoxide of nickel. The structural material is nickel-steel and the electrolyte is an aqueous solution containing preferably 20 per cent. by weight of potassium hydroxide (potash), the freezing point of the electrolyte being – 30° C. (=29° F.). According to Dr. Kennelly's paper, the positive and negative plates have the same structure mechanically, only the chemical contents of their pockets differing. Each plate is a sheet of steel 0·61 mm. (·024 in.) thick in which rectangular holes have been stamped to form a grid. A typical plate has three rows of eight holes, twenty-four holes in all, and each hole or recess is filled with the pocket or shallow box of nickel-plated steel containing the active material, the pockets projecting slightly beyond the surface of the steel grid. The pockets are perforated with numerous fine holes to admit the electrolyte to the active material, which is in the form of rectangular cakes or briquettes. After the boxes of active material have been placed in the grid, the whole is subjected to great pressure so as to close the boxes and clamp the whole mass into one solid and rigid steel plate. The nickel-plating of both grids and boxes assures good electrical connection between them. The positive briquettes, corresponding to zinc in a primary cell, are made by mixing and compressing together a finely divided iron compound with a nearly equal volume of flakes of graphite, the latter not having any chemical action, but merely assisting the conductivity of the briquettes. The negative briquettes, corresponding to the carbon in a primary cell, are made as above, a nickel compound being substituted

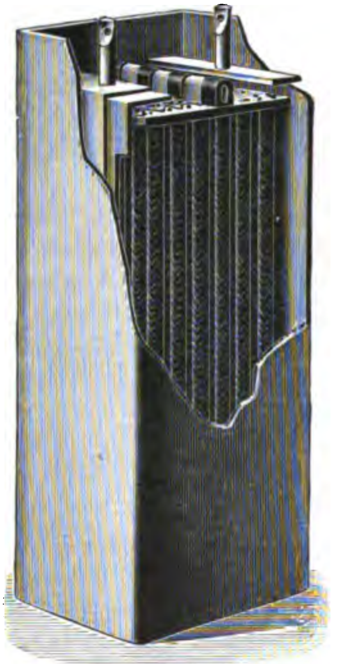


Fig. 312.—Max Accumulator.

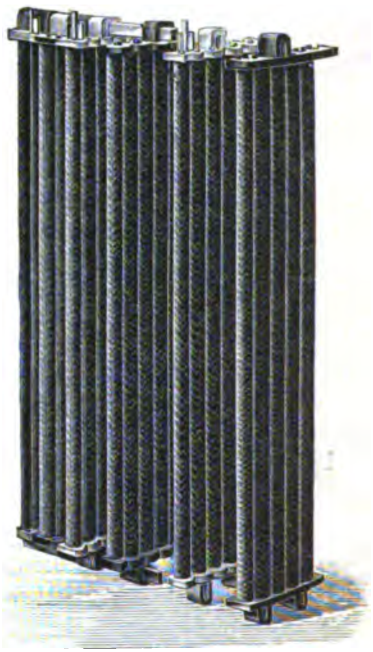


Fig. 313.—Max Electrodes.

for the iron. The weight of the electrolyte is expected to be not more than about 20 per cent. of the weight of the plate or 14 per cent. that of the whole cell. Dr. Kennelly gives the initial voltage of discharge after recent charging as 1·5 volts, and the mean voltage of full discharge as 1·1 volts approximately. The normal discharging current rate is 0·93 ampère per dm.^{2} (8·64 ampères per sq. ft.), and the storage capacity of the cell per unit of total mass is 30·85 watt-hours per kg. (14 watt-hours per lb.); that is, the battery weighs 32·4 kg. (71·28 lb.) per kilowatt-hour or 24·2 kg. (53·3 lb.) per electrical horse-power-hour. The mean normal discharging rate is 8·82 watts per kg. (4 watts per lb.), but the cell may be discharged at a relatively high rate in one hour approximately at a rate of 26·46 watts per kg. (12 watts per lb.). Dr. Kennelly says that the Edison cell does not appear to be injured by overcharging or high rates of discharging, only the electrical efficiency suffering under such treatment. Only every-day practice under the hard conditions of traction will show whether all the claims made for this cell can be substantiated in fact.

The table given on p. 306 demonstrates how the specific constants vary from one system to another, but as other interesting elements are not there estimated, such as durability, the figures there given are far from comparable. Their diversity proves only that the typical characteristics of the traction accumulator are yet far from being well defined. It was with the object of supplying this deficiency that the Automobile Club of France organised a trial competition, which was held in November, 1899, and which continued until all the batteries were out of service, although a period of six months was not to be exceeded. Its lessons cannot fail to be instructive, and to be the source of considerable progress. The figures given in the table on p. 306 were determined by testing fixed cells, but they may be accepted for automobile accumulators, because the periods of rest which frequently interrupted the discharge of traction accumulators and the motion in running favour diffusion of the liquid; consequently they permit calculation of the weight of accumulators necessary to run an automobile of a certain weight in certain known conditions of speed and of road profile. To assure propulsion of a car weighing one tonne (practically one ton) at a speed of 18 km. per hour (5 m. per second), quite sufficient for town work, it is requisite, with a co-efficient of traction of 2·5 per cent. (25 kg. per tonne) (56 lb. per ton), to give at the wheel tyre a power of 25 × 5 = 125 kgm. (904 ft.-lb.), this being the equivalent of about 1,250 watts. Assuming efficiencies of 0·8 for the electric motor, and 0·9 for transmission from its shaft to the axle, the accumulators should furnish $\frac{1{,}250}{0{\cdot}9 \times 0{\cdot}8}$ = say, 1,800 watts. They will be able to do so at the rate of 5 watts per kg. if their weight is $\frac{1{,}800}{5}$ = 360 kg. (792 lb.), say 36 per cent. of that of the car; and since in 1 hour they will expend 18,000 watt-hours to run the car for 18 km. (11·2 miles), this will be equivalent to an expenditure of 100 watt-hours per kilometre tonne (a kilometre tonne is equivalent to the work done in conveying 1 ton for 0·6 mile). These figures are somewhat greater than those obtained by Morris and Salom at Chicago, which varied from 84 to 92 watt-hours per kilometre tonne; but, as Hospitalier remarks, the experiments of the American engineers were made in eminently favourable circumstances, and the roads, especially, were very level. The hackney carriage trials of 1898 demonstrated that the expenditure could be reduced to 80 watt-hours per kilometre tonne. The accumulators giving 25 watt-hours per kg. (2·2 lb.) can keep up this speed of 18 km. (11·2 miles) per hour for 5 hours; that is, they can run the car 18 × 5 = 90 km. (56 miles) without recharging. Hospitalier thought these figures should be reduced by one-third so as to reckon losses due to stoppages, starting, errors in steering, and rising gradients. The vehicles which took part in the French hackney carriage trials of June, 1898, in nearly every case ran considerably further than the prescribed 60 km. (37 miles), and one of them even travelled 105 km. (65·23 miles). Yet in none of these vehicles did the proportional weight of the accumulators reach 36 per cent. of the total weight when loaded; it varied from 26 per cent. to 32 per cent. With such a proportion there is a somewhat large margin for the weights of the motor of the transmission gear and of the car and the passengers. Hospitalier estimates the relative weights of the various parts composing a car to carry two passengers and driver to be as in the table on next page.

The figures in the last two columns are very nearly those of the two-seat cabs which took part in the hackney carriage trial: thus in the Jeantaud drojki and the Krieger victoria the weights of the accumulators are 340 kg. (748 lb.) for total respective weights of

1,050 kg. and 1,180 kg. (2,310 lb. and 2,596 lb.). For cars with four seats the respective figures increase to 450 kg. and 1,770 kg. (990 lb. and 3,894 lb.) in the Kriéger cab, and to 450 kg. and 1,790 kg. (999 lb. and 3,938 lb.) in the Jeantaud landaulet. The proportion of these weights fall considerably, being about 25 per cent. instead of 33 and 30 per cent.

PARTS OF CAR, ETC.	Weight in kg.	Weight in lb.	Weight in kg.	Weight in lb.
Accumulators ...	—	—	300 to 350	660 to 770
Motor and transmission gear	120 to 150	264 to 330	680 to 850	1,496 to 1,870
Coupling, connections, accessories	50 to 80	110 to 176		
Body, frame, and wheels	300 to 400	660 to 880		
Two passengers and driver	210 to 220	462 to 484		
			Totals, 980 to 1,200	2,156 to 2,640

With regard to charging the accumulators, if the car is of the hackney carriage type the replacing of exhausted batteries by fully charged batteries, as done particularly by the Compagnie Français des Voitures Electromobiles, appears to be the best system. This has the great advantage of not storing the carriages during the lengthy operation of charging. It would be in vain to increase the number of charging stations in a town, with the idea of making practical a system of rapid charging, without removing the accumulators, because accumulators that would be suitable have only very slight specific capacity, say 2 to 3 ampère hours per kg. (2·2 lb.). Hackney carriages can carry fixed accumulators and have them charged at the depôts, but this involves keeping them for a long time at a standstill and necessitates a number of charging depôts. On the other hand, this system is available for private owners, whose houses are connected with the town electric service; in such cases recharging can proceed during the night. In any case the accumulators will be assembled in series for charging. An alternating current must be converted to a continuous current, and this will cause complication.

The advantages of the electric motor from the point of view of traction will now be considered. The accumulators send their current to the electric motor which drives the car; the torque furnished varies with the number of conductors on the armature, the intensity of the magnetic field and of the current. As will be explained, the two latter may be caused to vary and consequently the torque, in fact the latter may attain values up to eight times the normal, thus affording a valuable elasticity for starting and extra strains. There is nothing like this in the petrol motor, the torque of which is constant; the only available method to make the latter vary is by change of speed (*see* p. 344). Moreover, as the speed of the motor decreases the power may increase and inversely: thus the motor is self-regulating. In certain circumstances the power may reach zero and then become negative in value, the motor acting as a brake and working as a dynamo, being then capable of recharging the accumulators. It is by means of the controller that the variations necessary for alterations in the motor torque are given to the intensities of the magnetic field and the current. The controller likewise also allows for starting, changes of speed, working of brake, stoppage and reversing. There are various methods of exciting, and varying the excitation, of the motor. Separate excitation, current for the purpose being taken from some of the accumulators and sent through the field winding, gives a constant magnetic fluid and a speed which depends upon little else than the difference of potential at the motor terminals. The controller regulates this speed by inserting variable resistances in the circuit, or better by coupling the accumulator batteries in different ways. The magnetic field being constant, as soon as the speed of the motor exceeds a certain rate it begins to work as a dynamo, acts as a brake, and can serve to send to the cells part of the work produced by the running of the car. In spite of these indisputable advantages separate excitation is little used owing to the complications which ensue in recharging. Unequal discharges of the accumulators affect the excitation. This simple difficulty of recharging deserves to be taken into consideration, because renewal of the energy is one of the greatest inconveniences in the employment of accumulators. Series excitation, in which the field coils carry the armature current, is the simplest system; it is often employed, and is combined with the varied coupling of the batteries, but with it the speed of the car varies with the gradient of the road, irregularity in speed resulting. Shunt excitation, obtained by sending a small portion of the accumulator current through the field coils and the major portion through the motor armature, requires a special device for starting to avoid burning out the motor, but once the motor has commenced work this method has the advantages of separate excitation. Sometimes the field winding is in two coils, which the controller couples in series at starting and in parallel for running at full speed. Thus two motors can be utilised, each driving a wheel and making it possible to dispense with the differential gear generally requisite to assure independence of the driving wheels when turning the car. The methods of coupling these two motors, and of their excitation, together with coupling of the batteries supplying the current, make possible, says Hospitalier, a great number of combinations to graduate speed, but they complicate normal working. The most delicate combinations are

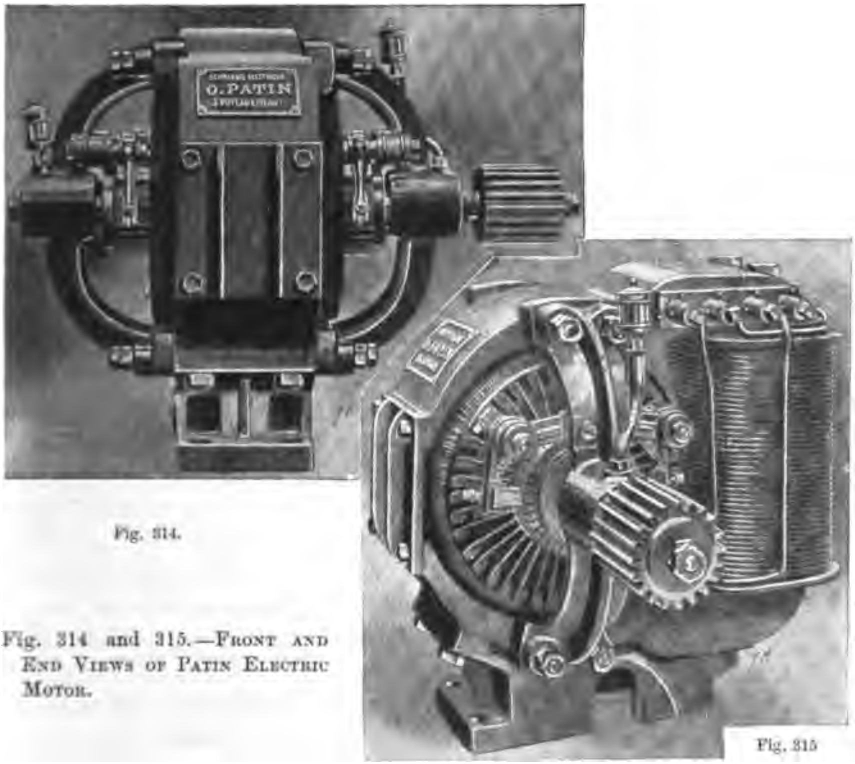


Fig. 314.

Fig. 315

Fig. 314 and 315.—Front and End Views of Patin Electric Motor.

moreover, assured by extremely simple movements which merely require that the driver should have an idea of the result to be obtained. Thus for starting, for reversing, and for stopping the controller easily gives all these motions by admitting, reversing, or cutting off the current through the armature. This explains the great pliancy and extreme ease in handling electric automobiles.

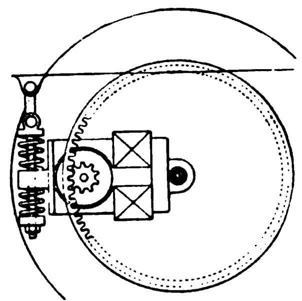


Fig. 316.

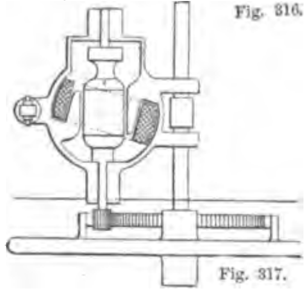


Fig. 317.

Figs. 316 and 317.—Typical Two-pole Electric Motor and Driving Gear.

The qualities required from electric motors for traction purposes will now be considered. The electric motor, as usually constructed, supplies the rotary motion so suitable for automobiles, because it suppresses the vibrations inherent in alternating motors in a manner which as yet has not been made practicable with steam and still less with petrol. As the electric motor has had comparatively few applications to cars, it has not yet been possible to make all the improvements which will render this motor more suitable than it is naturally for easy starting, simple handling, and for working with currents of low tension. Endeavours will also be made to make it stronger and lighter; thus Patin for his motor (Figs. 314 and 315) constructed two supports of aluminium not required to do much work. Another quality required is slow speed, so that the reduction of speed between the armature shaft and the driving-axle can be avoided, or, at least, greatly simplified. The speed-reducing gears are noisy and expensive, and even when made of steel, instead of indurated or green leather or bronze, they very soon wear out, especially if not protected by cases; also they entail great loss by friction. Moreover, a slow, angular speed does not exclude fast tangential speed favourable to the development of electro-motive force. Consequently, the diameter of the armature should be made as large as is allowed by the space available for it, and by the risk of injury to the winding caused by excessive centrifugal force. Tangential speed has been brought with impunity to 25 m. (82 ft.) per second. These two conditions, lightness and slow angular speed, must, however, be combined with another, namely, sufficient power. It is somewhat difficult to reconcile all three, because the simplest way to give great power to a light motor is to make it rotate rapidly. Besides, it must be remembered that a light motor is not always preferable to a heavy one, nor a slow motor to a rapid one. It may happen, for example, that a machine weighing less than another, but inferior in efficiency, will require an increase in the weight of accumulators, much greater than the gain realised by its excessively light structure. The consideration of total efficiency should really outweigh all others, because the problem is to carry a given load with the minimum expenditure of energy.

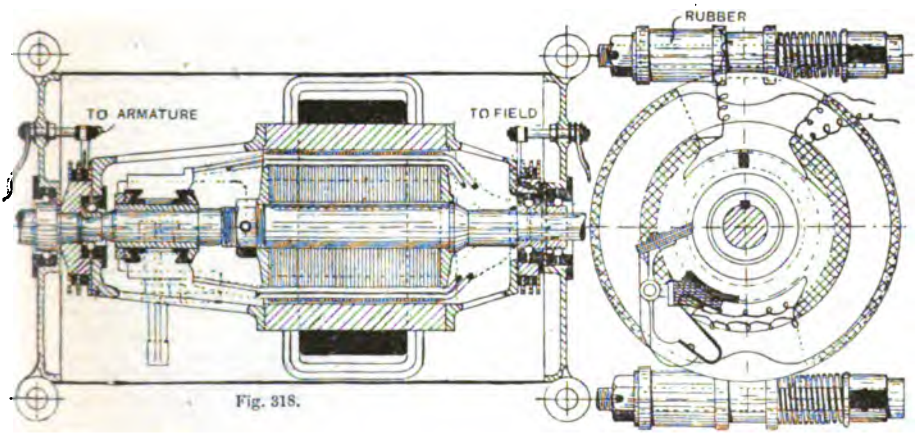


Fig. 318.

Fig. 319.

Figs. 318 and 319.—Section and End View of Still Electric Motor.

The special design of electric motor for automobile use is of light weight compared with the stationary motor, its efficiency is high, and it can bear an overload of 100 per cent. for short periods.

A typical two-pole motor and driving gear is shown in side view by Fig. 316. The motor is pivoted at one end on the carriage axle and the other end is suspended from the carriage between two spiral springs on a jointed hanging rod, the springs (1) allowing of up and down movement and (2) diminishing the sudden strain of starting due to the inertia of the car when the current is sent through the motor. A pinion on the end of the armature gears into an internally toothed ring attached to the spokes of the road wheels, as illustrated. Fig. 317 is a plan of the motor and gear, but with a Lundell two-pole single coil motor as used extensively in America.

The Still electric motor is shown in part by Figs. 318 and 319. Its slotted drum armature is secured to the right-hand shaft and runs in a ball bearing inside the field magnet extension, the two-pole field magnets being rigidly secured to the left-hand shaft and run in ball bearings at each end; of course, the armature and fields revolve in opposite directions; the armature drives a sprocket on one side, and the field magnets a sprocket on the other side. The whole motor is supported in a casing on four spiral springs attached to the underside of the carriage. The advantages of the double action are

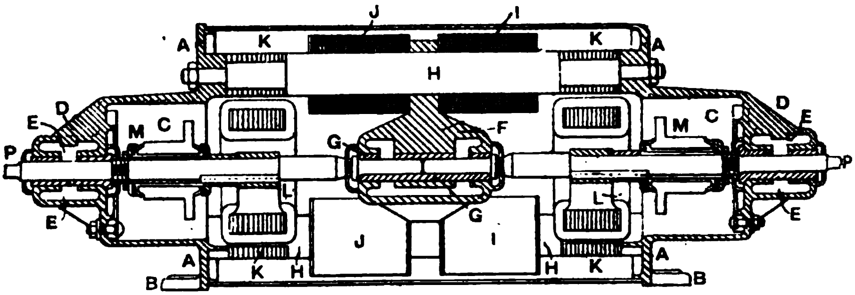


Fig. 320.—Sectional View of Mildé Electric Motor.

a reduction in the armature speed and the independent driving of the two road wheels with the absence of a differential gear; but extra bearings are required, and there must be additional rubbing connections to convey the current. Ball bearings obviate additional friction. This system is not so simple as a single motor with differential gear or two motors acting directly on each wheel independently. The contact rings at the right end of the field magnet revolving part are connected to the windings of the magnets, and the rings at the left end to the brushes resting on the commutator, which has thirty sections; ordinarily the brushes are of copper, but for higher voltages are of carbon. The fields are series wound in two layers of different gauge wires, that is, each bobbin has two windings. The motor is designed to work at either 80 or 160 volts at a current of from 12 to 15 ampères, but it will stand an overload of from 85 to 100 per cent. for reasonable periods when hill-climbing.

The maximum effective speed is 1,000 revolutions per minute, and the weight of the complete motor is 79·5 kg. (175 lb.).

The Mildé electric motor has two armatures keyed on separate shafts in line with each other; there are four exciting coils on each side of the central bearing for the two shafts, four of them being shunt wound and the other four series wound. A shunt coil faces and has on each side of it a series coil, while diametrically opposite to it is another shunt coil. Fig. 320 is a longitudinal vertical section of the motor on line X X of Fig. 321, and the latter is a transverse section through K K, Fig. 320. Two brackets made of diamagnetic metal, A, carry each a cast metal frame, C, to which is fixed a plummer block, D, carrying a bush, E. The brackets are fixed to a support by means of lugs, B. Four steel rods, H, secured by nuts, support midway between the brackets a plummer block, F, which has bushes, G. These four rods are the cores of the exciting coils. Each rod carries two of these coils, I J, one on each side of the central plummer block; each rod also carries two pole pieces, K, which nearly surround two ring or drum armatures, L, whose collectors, M, are in the frames, C. The shafts to which the armatures are keyed turn in bushes, E G, and are driven by means of gearing on their projecting ends P. The two armatures are independent of each other, and can turn together or in opposite directions. The eight coils are arranged four on each side of the central plummer block, so that a coil, I, with shunt winding, has facing it and on each side a series wound coil, J, and another shunt coil, I, diametrically opposite it, the object being to obtain a symmetrical and balanced magnetic field whether series or shunt excitation be employed separately or simultaneously. The magnetic circuits excited by this field are four in number, proceeding symmetrically from a north pole to a south pole, passing through the armatures and the cores, submitted to the influence of two coils, I, and two coils, J. The two armatures are thus always in the same magnetic field, and each can turn at the most suitable speed for the wheel which it drives, the two being quite independent.

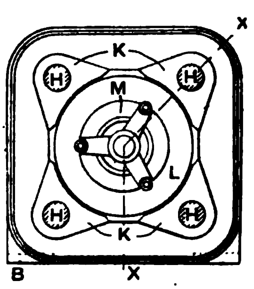


Fig. 321.—End View of Mildé Motor.

The Kriéger motor is of the four-pole type, and it is illustrated by Figs. 322 and 323. It has four excitation coils, two of which are wound with thick wire in series and two with thin wire in multiple circuit. The drum armature makes from 2,000 to 2,600 revolutions per minute. Fig. 324 is a diagrammatical side view of the motor, suspension and driving gear. Two motors are used, and on each a pinion gears into a toothed ring attached to one of the front road wheels. Each motor is suspended from an arm pivoted to the road wheel axle, and is supported further by a strong plate-spring fixed at one end to the axle and having at the other end a connecting link attached to the other side of the motor casing. The spring allows of movement, as in the example shown by Fig. 316.

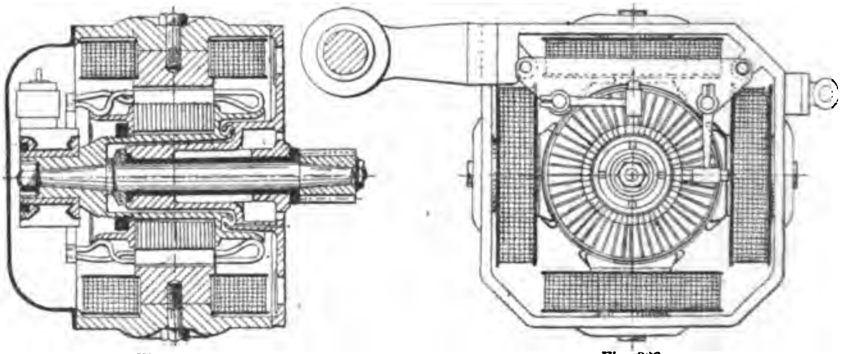


Fig. 322.
Fig. 323.

Fig. 322 and 323.—SECTION AND END VIEW OF KRIÉGER ELECTRIC MOTOR.

The de Dion-Bouton light electric car employs a slow-speed and consequently comparatively heavy motor, running at 800 revolutions per minute. It directly drives the differential gear on the back axle in the well-known de Dion-Bouton style. It is of the four-pole type, and is enclosed completely in an aluminium casing. There are inspection apertures on the commutator side near the brush holders. The brushes are normal to the commutator, as usual, and the armature is drum-wound and has a tooth core.

The Joel twelve-pole electric motor has its armature and commutator illustrated by Fig. 325. Of the motor, Fig. 326 is a longitudinal section, Fig. 327 is a side elevation, and Fig. 328 is a plan of the field magnets. The shaft A is held stationary in the outside casing which secures the motor to the underframe, and the fixed field magnets L carried by the shaft are in two pieces bolted together as shown, and carrying between them and inside their pole pieces N S the magnetising coil V. There are twelve poles, the six north poles interlacing alternately with the six south poles, and all the pole pieces lie in the same radial plane. Mounted about the shaft A, and free to revolve upon it, is a sleeve carrying the armature Y, the commutator Z, and the driving wheel P. The armature is a laminated iron ring bolted to the spider arms *y*, and slotted transversely around its inner face. Each of the slots T carries two insulated square copper wires *w*, the wires being connected about the sides of the ring to form overlapping complete windings about the whole armature. There is an extra slot for connecting the final ends of the windings in series. The general system of this zigzag winding crosses the armature twelve times in one complete coil, as shown by Fig. 325, which shows also the connections to the commutator. In the larger motors more than two wires are laid in each of the slots T. This method of construction is claimed to reduce weight and to reduce the amount of ineffective copper. The Joel voiturette has two of these motors fixed to the

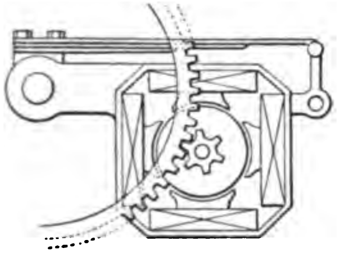


Fig. 324.—Suspension of Kriéger Motor.

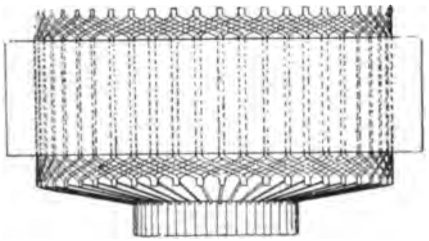


Fig. 325.—Armature and Commutator of Joel Motor.

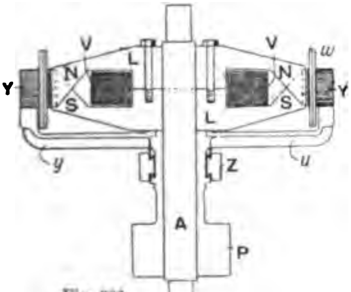


Fig. 326.

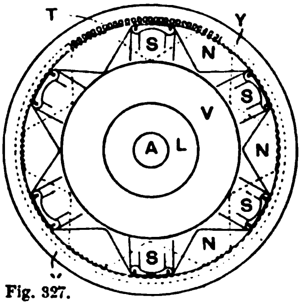


Fig. 327.

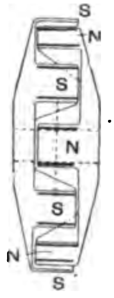
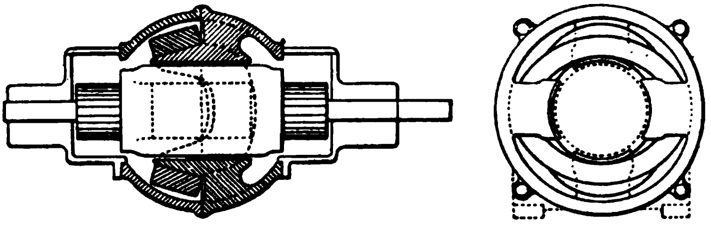


Fig. 328.

Fig. 326.—Longitudinal Section of Joel Electric Motor. Fig. 327.—Side Elevation of Joel Motor. Fig. 328.—Field Magnets of Joel Motor.

frame, each driving one of the rear wheels of the vehicle by a chain. Each motor weighs 50·9 kg. (112 lb.), and the two can develop normally 2 h.p. at about 700 revolutions per minute; they are said to bear an overload of 100 per cent., and their efficiency at an E.M.F. of 40 volts is given as 70 per cent. at half load, 85 per cent. at normal load, and 89 per cent. with a 50 per cent. overload; these are the inventor's figures, it is believed. The motors are shunt-wound, and are enclosed completely in an aluminium case containing also the spur gearing.



Figs. 329 and 330.—Section and End View of Joel "Sine" Motor.

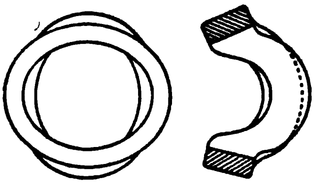


Fig. 331.—Field Coil of Joel "Sine" Motor.

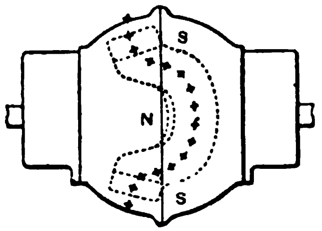
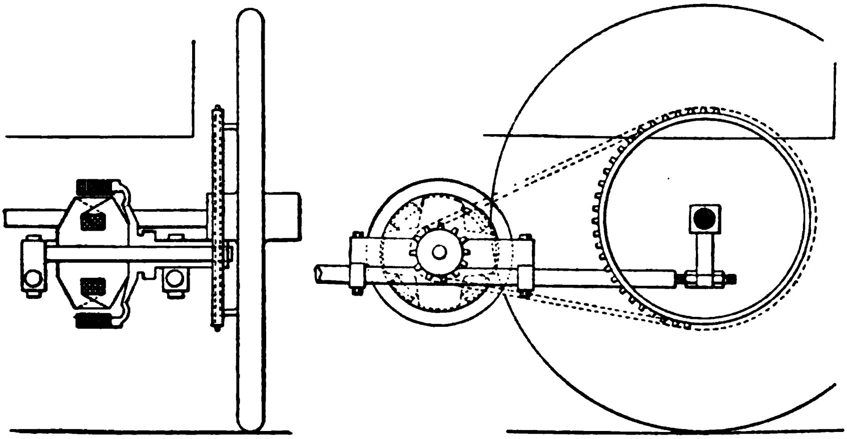


Fig. 332.—"Sine" Curve Magnetic Field of Joel Motor.

The Joel new "sine" motor shown in section by Fig. 329 and in end view by Fig. 330 is of the four-pole type, and spherical in shape. The iron casing carrying the poles is divided centrally into two halves, the two halves with their two poles each interspacing when placed together. The form of single field coil used for magnetising the four poles is shown in Fig. 331, whilst Fig. 332 is a diagram of the "sine" curve magnetic field. The coil is wound directly on a ball mould or spherical former, or is wound first as a simple ring and afterwards pressed or moulded into the required shape; it has two curved indentations alternating with curved raised parts, sinuous in shape, hence the name "sine" motor. The coil is placed in position on one half of the iron casing partly embracing and including the two poles on the magnetising sphere of the coil, the other half of the iron casing with its two poles fitting into the depressions of the coil, and in turn being also included in the magnetising sphere of the coil. The one coil magnetises the four poles alternately in two pairs, N N and S S. There is the advantage of reduced weight. Such a motor with a double-wound armature and two commutators is claimed to weigh only 85·4 kg. (190 lb.), to give 6 brake h.p., and to have an efficiency of 87·5 per cent., its exciting energy being 70 watts.



Figs. 333 and 334.—Suspension of Joel Electric Motors.

H. F. Joel has designed the method of suspension shown in vertical section and side elevation by Figs. 333 and 334. A flexible and independent tubular underframe supports two eight-pole motors whose armatures revolve outside the fields, thus differing from other motors. The armature has a long sleeve bearing upon whose end a small sprocket chain drives a large sprocket attached to the road wheel spokes. The chain can be adjusted by means of the screwed pin and lock-nuts fixed at the end of the supporting tube. The motor weighs 50·8 kg. (112 lb.), and gives 2 brake h.p. at 700 revolutions per minute. It is claimed to run sparklessly, to stand an overload of 100 per cent., and to have an efficiency varying between 80 and 90 per cent. Mr. Joel states that these motors have run for six months at a time without other attention than oiling the bearings.

The Waverley six-pole shunt-wound motor is shown complete by Fig. 335. The manner of gaining access to the brushes is made clear in Fig. 336, and the field magnets and other constructive features are illustrated by Figs. 337 and 338. The armature R and commutator R^1 are shown in Fig. 339. The normal output of 3 h.p. can be exceeded considerably for short periods. The circular field magnets M have six inwardly projecting poles, each surrounded by a winding, Q. One pair of wires is connected with three adjacent coils, Q, in series, and another pair with the other three, also in series. The bearings of the ring lubricated type, are provided by end castings, M^1 and M^3, which are bolted to the field magnet M in the manner shown. The casting M^1 has the flange M^2 formed upon it for the bolting of the motor to the rear axle, the flange being eccentric to the armature shaft, since the holes in it (through which the holding bolts pass) are slotted, the gear wheel on the shaft can be adjusted into mesh with the wheel it drives by sliding the flange round about its axis. The other casting, M^3, encloses the commutator R^1, and the four carbon brushes P, the latter being fixed to insulated blocks secured to it. The

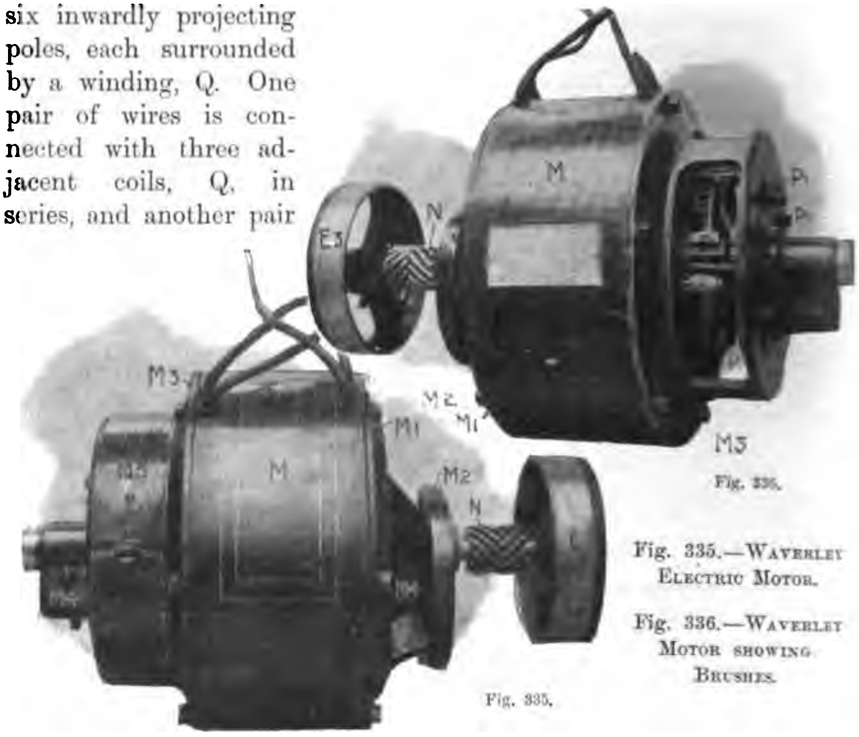


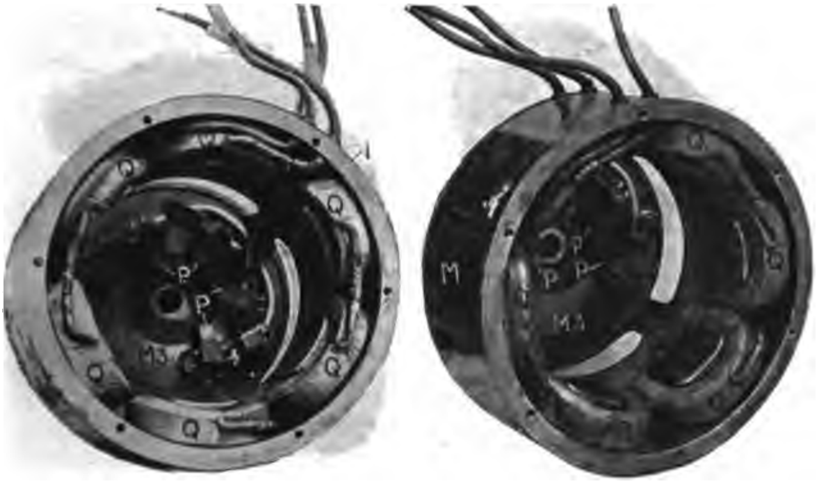
Fig. 336.

Fig. 335.

Fig. 335.—Waverley Electric Motor.

Fig. 336.—Waverley Motor showing Brushes.

brushes are electrically connected together in pairs, the first and the third, and the second and the fourth being joined together by insulated wires. The wires leading from the armature to the controller pass from the external terminals P^1. The casting M^3 has openings, as seen in Fig. 337, which are normally covered by a sheet-metal ring, M^6 (Fig. 335). The ring renders the motor dust proof and the brushes easy of access. The reservoirs, M^4, for the oil in both bearings form a part of the castings M^1 and M^3, both bearings are of ample length. The drum-type armature R, clearly shown in Fig. 339, is wound in a special manner, and its shaft is fitted with the double helical pinion N, and terminates in the brake drum E^3. The corresponding spur wheel on the differential has, of course, teeth of a



Figs. 337 and 338.—Waverley Motor Field Magnets, etc.

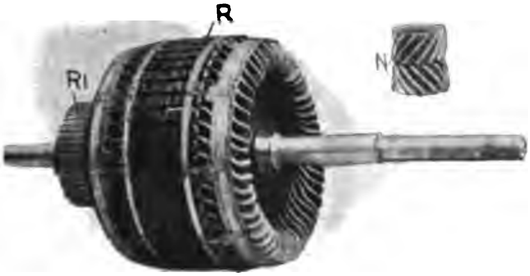


Fig. 339.—Waverley Motor Armature.

similar shape, and is of large size. The use of this "herring-bone" type of gear, although considerably more expensive to make, is amply justified by the smoothness and silence of running ensured. In the double motor equipment the differential gear is dispensed with, and each half of the live axle terminates at the inner end at a double helical spur wheel. The two motors are fixed to the casing which encloses the gear wheels, one on each side of it, and similar pinions to those here illustrated are fixed on the inner ends of the armature shafts ; the motors are only connected with one another indirectly, and this mostly through the rear wheels by the road. By this arrangement one motor drives each of the rear wheels, and the necessary differential action is secured without the mechanical complication involved by a differential gear.

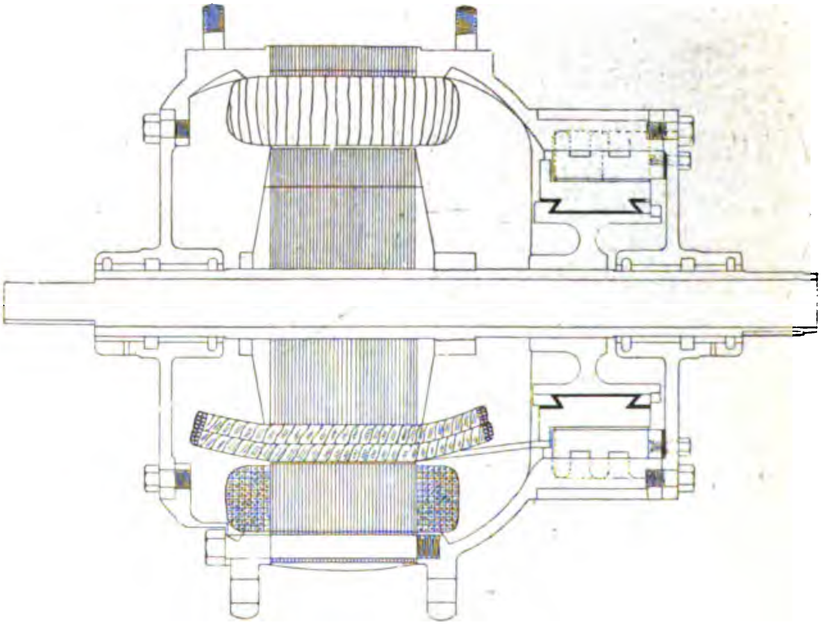


Fig. 340.—National Electric Motor.

In the Bouquet Garcin and Schivre motor one or both of the two armatures can be used according to the power required.

On the Centaure (American) electric car are employed ball-bearing Westinghouse motors, whose winding, being arranged in halves, allows of a four-speed series-parallel system of control.

The Lundell motor is widely used. A new vehicle employing it is the electric four-seat Surrey of the Accumulator Industries Company. On this vehicle the two motors are octagonal, and are double armatured. Their normal power is 5 h.p., but they can give twice that for short periods. They are separately excited, the three normal speeds being obtained by changing the connections of the four armatures, the cells being always connected in series.

The electric motor used on the National Vehicle Company's car (American) is represented diagrammatically by Fig. 340. It is of the six-pole iron-clad type, is series wound, and has laminated fields and armature. The bearings are self oiling. Its power is 2½ h.p. at 1,400 revolutions per minute.

The Richter (American) electric motor wheel is a curious construction. The rim of each road driving wheel forms the armature of a motor, this armature being arranged outside the field magnets in a somewhat similar manner to the Joel motor. A multipolar fixed field magnet is carried on a spider, which is keyed to the stationary axle, and on either side of which are ball bearings on which the road wheel rotates. The wheel rim armature makes a dust-proof fit against the spider, and the conducting wires are carried inside the spider and out through the axle hole. Each wheel is, of course, independent. Slow speed being essential, the motor is of great weight, but then the use of all transmission gearing is obviated.

Electric motors on automobiles spark excessively when overloaded, and the field magnets, but more particularly the armatures, become hot. Possibly, a partial remedy would be the employment of field magnets with double-slotted cores, on the Phœnix (American) system (*see* Fig. 341). In this, oblong holes connect the slots with the air in the armature space; and the sides of the cores are cut away so as to produce greater magnetic density at the horns. The field magnet illustrated was designed for dynamo use, and it has been found that a dynamo so built stands considerable overload without sparking, whilst the fields are kept extremely cool by the air in the slots being able to circulate through the holes.

In the construction of car motors the materials must be carefully selected, soft steel being used for the magnets, which are saturated at full load in order to completely utilise the metal.

For the same reason motors are often made with several poles, say four. The air gap is made as narrow as possible, but not less than 3 mm. (0·12 in.). The section of the armature wire is such that the density of the current may be 5 or 6 ampères per mm^2. (0·0015 in.); in these circumstances the temperature of the winding does not exceed 50° C. However, provision must be made for an increase of current of 50 per cent., to say nothing of the 10 or 12 ampères required at starting, when the temperature attains 90° C. Thence results the necessity of employing very effective insulation, and preferably excitation in series. To avoid sparks at the brushes without being obliged to move the latter, which is impossible with a motor that has to turn in both directions, carbon is used (about 15 mm^2., ·02 sq. in., in section per ampère). Endeavours are also made to reduce the reaction of the armature, which causes variation in the position of the neutral line. This reduction can be made by giving the magnet a great number of ampère turns, which approximates to saturating it; this should be done, as was explained, to fully utilise the metal. This also leads to an increase in the number of magnet poles; the armature reaction decreases as their number is increased. The four-pole motor has also the advantage of having a very compact form, allowing a very large diameter to be given to the armature, and also being very adaptable to a casing. When the latter is left open at both ends, it merely protects the coils against the effect of shock, which is something; but when entirely shut it keeps out moisture, dust, and bits of metal, which, attracted by the magnets, might fill the space between them and the armature. A close casing has only one defect—that of keeping all air away from the coils and thus subjecting them to great heating. As a remedy for this a few openings are sometimes made at points through which the dust and particles of metal are least likely to enter. These advantages have led to an extensive employment of the four-pole motor. As a rule, the four brushes corresponding to the four poles are not retained; two of them are omitted, the necessary connections being made on the armature windings. Thus the motor is simplified, the chances of imperfect contact decreased, and supervision made easier. Sometimes, however, there are four brushes, and the armature winding comprises two sets of coils, each terminating at a collector and constituting two independent circuits.

The means employed to vary the speed of the car consists almost exclusively in altering that of the motor. This can be done in three ways: (1) by acting on the voltage of the motor terminals, (2) by modifying the strength of the magnetic field, (3) by coupling the armature coils in various ways. These three methods can each be varied in several ways. The first can be conveniently operated by the insertion in the armature circuit of a rheostat, the resistance of which can be varied. However, this method has the inconvenience of involving loss of energy, this being employed to heat the rheostat, which it brings to a high temperature. For these two reasons when it is employed its use should be limited to starting, and to some other purposes, where it is only required for a brief period of time.

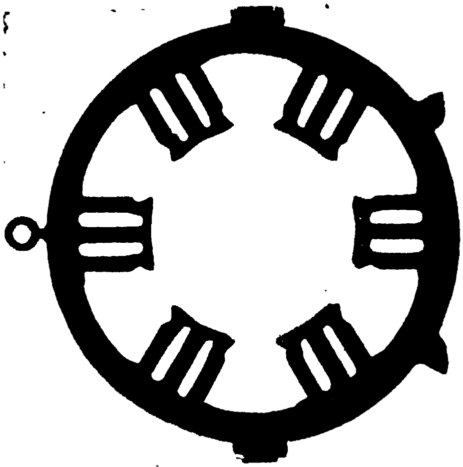


Fig. 341.—Phœnix Field Magnet.

A better way of varying the speed consists in coupling in various ways the accumulator batteries. If, for example, these comprise 40 cells, each having an electro-motive force of 2 volts and arranged in four batteries, parallel coupling of the four gives an electro-motive force of 20 volts, sufficient for slow speed; the coupling in parallel of two pairs of batteries arranged in series gives 40 volts for average speed; and coupling of the four batteries in series gives 80 volts for the highest speed. For intermediary speeds it is merely requisite to vary the number of excitating accumulators, or to place a variable resistance in the exciting circuit.

The simplest form of control, according to H. F. Joel, is the Northey system, employed in the Electromotive Force Company's cars, in which the batteries are grouped in different combinations: with, say, 40 cells, there are 4 groups of 10 in parallel, 2 groups of 20 in parallel, or 1 group (all 40 cells) in series. Changes are made by joining groups of cells, intermediate between the required changes, so that there may not be any breaks in the circuits.

The field excitation can be modified in two ways:—1. By inserting between the terminals of the field circuit a variable shunt resistance; the lower this resistance the greater will be the proportion of current passing through it, and the less that passing in the field coils. 2. By varying the number of ampère turns of excitation. This variation can be obtained by acting either on the current or on the number of turns; in the first case the various sections of the field magnets are connected in series or in quantity; in the second, the number of the sections of the coil inserted in the circuit are varied, but this is not done because in this way the magnet is badly utilised at high rates. Finally, the armature windings can be coupled in the case of four-pole motors in series and in parallel. When the car is driven by two motors, by coupling them in series or in parallel, one can vary from single to double, at equal speed, the generated counter electro-motive force. With equal couples the speed obtained in the first case will be double that obtained in the second. At starting, the two motors in series produce the same total couple with half the current that would be used were they in parallel. Some makers use a system of gearing which gives mechanically never more than two speeds; by doubling the number of speeds electrically obtained this device gives a most extensive range. Of course, the processes just described are very often combined in the same carriage, according to the taste of the maker. D. Dujon recommends coupling the batteries and armatures, merely acting on the field coils by varying the current, and not by altering the number of effective turns. As he himself admits, the solution is much less simple, and must vary with circumstances.

The controller is an apparatus which governs the various movements just enumerated; it is called also the speed regulator.

It is a commutating switch or circuit changer; and generally the series-parallel controller in use on electric railway and street cars is adapted for the purpose. As change of speed is required it groups the batteries in series or parallel, the motors in series or parallel, or combines the two. It acts by establishing various couplings between the different parts of the electric mechanism such as accumulator terminals, motor brushes, armature and field magnet windings, rheostats, etc. With this object each of the parts is connected by conductors to a commutator terminal, and the terminals themselves communicate with brushes rubbing against contacts which assure the required couplings. Fig. 342 shows a convenient method of constructing this device; the commutator terminals A are arranged in a line parallel to a cylinder, B, upon which the contacts C are placed; the brushes D, fixed on the ends of metal springs E, communicate with the terminals and are tangential with the cylinder. Each set of contacts is also similarly arranged, the contacts being connected in a suitable manner by

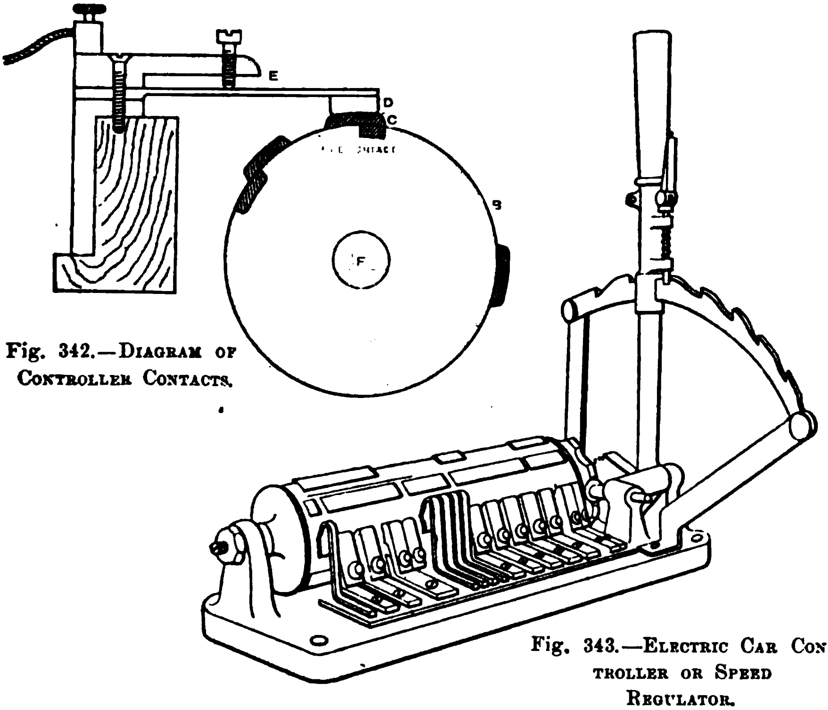


Fig. 342.—DIAGRAM OF CONTROLLER CONTACTS.

Fig. 343.—ELECTRIC CAR CONTROLLER OR SPEED REGULATOR.

metal conductors buried in the insulating cylinder. By aid of a handle the cylinder can be turned around its centre F so as to bring under the brushes the set of contacts corresponding to the movement to be made.

A typical controller, as shown by Fig. 343, consists of a cylinder of insulating material round which longitudinal strips and plates of metal are fixed in a certain order, whilst a number of insulated contact arms or spring blades press on the strips and are connected with the batteries and motors. Fig. 344 is a view of the cylinder surface developed, and shows the position of the metal strips and plates and the spring-contact blades. The motion of the hand lever turns the cylinder into the eight set positions, which respectively make the following combinations, as shown in the diagrams of the circuits, Fig. 345. (1) The two batteries are joined in series for recharging, the motors being cut out. (2) Slow speed back; field coils reversed. (3) Stop: motors short-circuited act as brake; batteries cut out. (4) Slow speed forward: motor in series. (5) Medium speed, 9·65 km. (6 miles) per hour for hill-climbing; motors in parallel, batteries in series; all working at highest efficiency and greatest power. (6) Higher speed, 12·9 km. (8 miles) per hour; resistance in field coils. (7) 16 km. (10 miles) per hour; additional resistance in field coils. (8) 19·3 km. (12 miles) per hour; all resistance in field coils; motors overrun at double normal speed of No. 5.

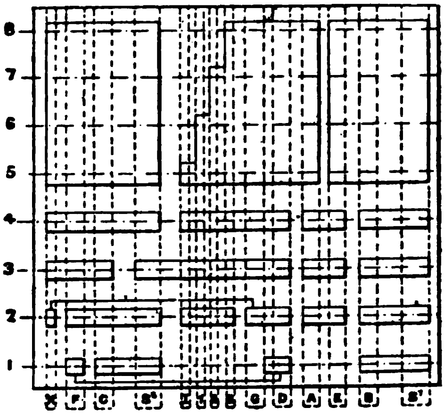


Fig. 344.—SURFACE OF CONTROLLER CYLINDER SHOWING CONTACT STRIPS.

The greatest power being required for hill-climbing, the speed is made appropriate, as in the No. 5 position above, and the maximum discharge from the battery is kept within a pre-arranged limit. For running on level roads at higher speeds the motors are overrun, and for slow speeds they are connected in series. This system employs shunt-wound motors only, and thus when the speed exceeds the normal, they act as dynamos and give a back charge to the batteries; also when the car is stopped, the momentum returns some current to the batteries.

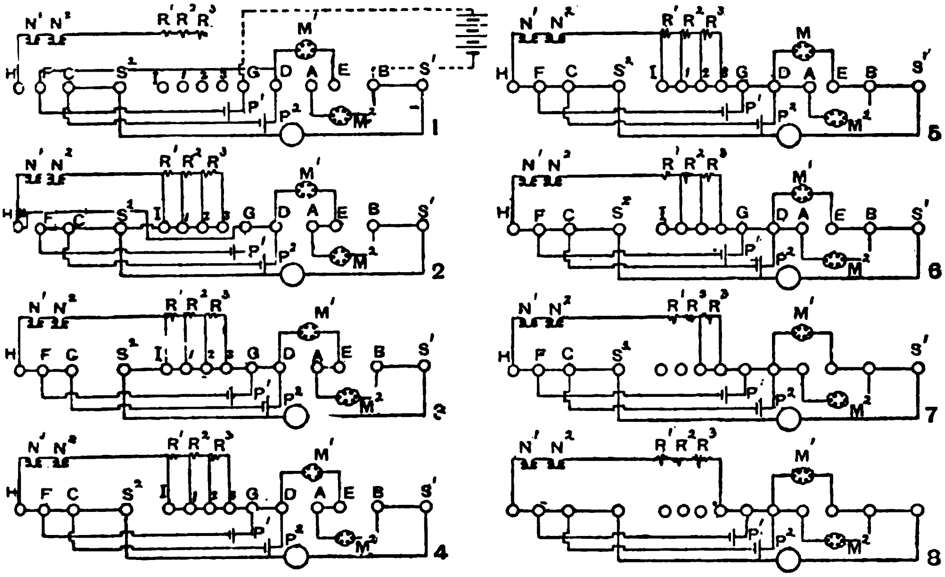


Fig. 345.—Combinations of Battery and Motor.

The Jeantaud system of speed regulation is shown by Figs. 346 and 347. For slow speed forward two batteries in parallel are in circuit with a single compound-wound electric motor (*see* Fig. 346). For the third speed forward the connections are altered, and the batteries are in series.

In one type of Kriéger car having two compound-wound motors, the circuits are as in Figs. 348 to 351. At slow speed forward the batteries are in parallel and the motors in series (Fig. 348). At higher speed, the batteries also are in series (*see* Fig. 349). By cutting out the series field coils and thus weakening the field magnets (*see*

Fig. 350) speed is increased further, and the motors become shunt-wound only, and when running at more than their normal speed, say, when going down a steep hill, they act as dynamos and give a back or recuperative charge to the batteries, and act as a brake to the car. To give the maximum power and the highest speed, the batteries are in series and the motors in parallel, as in Fig. 347, the reverse of Fig. 348.

The electric motor, as stated in the general account of its advantages (*see* p. 318), can convert to electrical energy part of the work produced by the running of the carriage. Thus, when descending an incline, the motor, no longer receiving current from the battery, is driven like a dynamo, and furnishes current, which is sent to the accumulators. Unfortunately this action is only possible with machines turning always in the same direction, whether they work as motors or as dynamos—that is, when a machine passes from one role to another, the current only changes its direction in one of the two parts, armature and field coils. This is only so with shunt motors. Now many traction motors have excitation by series. To employ them in this way the precaution stipulated for working the brake must be taken (*see* below), which complicates their construction. All accumulators, also, are not suitable, particularly those in which intensity of the charge must not exceed a certain rather low limit.

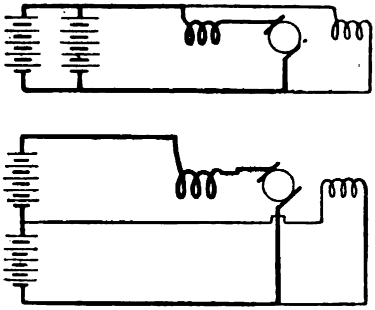


Fig. 346.

Fig. 347.

Figs. 346 and 347.—Jeantaud Combinations for Speed Changing.

If, instead of employing the kinetic energy of the carriage to turn the motor as a dynamo charging the accumulators, it is employed merely to produce a current that is transformed into heat by its passage into a suitable resistance, the motor acts as a brake, the power of which varies in inverse proportion to the resistance interposed. When the latter is slight, the motor being almost short circuited, an almost instantaneous stoppage is obtained, but this should not be done when the carriage is running full speed except in imminent danger, because there is a risk of burning the armature windings. The electric brake is very suitable for a series motor; the only precaution that need be taken when putting on the brake is changing the direction of the armature or magnet current so that it may become a generator, turning in the same direction as it did when a motor. It is less suitable for a shunt motor.

Fig. 348.

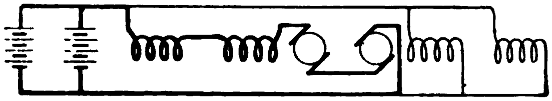


Fig. 349.

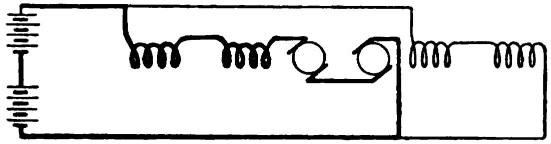


Fig. 350.

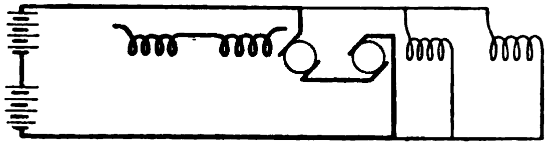
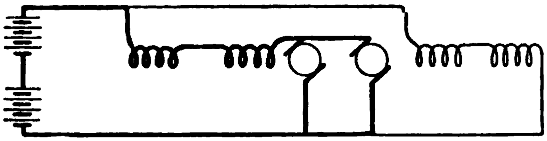


Fig. 351.



Figs. 348 to 351.—Kriéger Combinations for Speed Changing.

CHAPTER IX.

STEAM, PETROL, AND ELECTRIC MOTORS COMPARED.

Now that it has been shown how the three agents, steam, petrol, and electricity are applied in the propulsion of automobiles, it will be easy to point out their relative advantages.

Of steam motors, only the alternating type hitherto has been employed extensively, and this has not that continuity of action possessed by the rotary motor which offers itself as the type of road car motor; none the less, the alternating motor is very suitable for the purpose, and no other proof of this than the locomotive is needed. Rectilinear and alternating though it is, the motion is very simply transformed by aid of a connecting rod and a crank into a rotary continuous motion, and the steam exerts its pressure on the piston without jarring, quite different from the petrol motor. The steam road motor, as it is and must remain, is extremely simple, and composed of durable parts; consequently its working is very reliable, and if deranged it can easily be repaired. Considered apart from the boiler, it is for equal speed and power lighter than the petrol motor, this being accounted for by the fact that in a four-stroke-cycle petrol motor there is only one driving stroke in four, whereas in the double-acting steam motor every stroke drives. Moreover, the volume of air requisite to completely burn the carburetted mixture is, on account of the burnt gases remaining from the previous explosion, much greater than indicated by theory, and so the explosion chamber must be larger than that calculated theoretically. The relative lightness of the steam motor even increases with the power of the motor; but the boiler is essential, and its weight has to be considered, it then appearing that the petrol motor gives a greater efficiency than the steam motor and boiler, weight for weight. However, the chief advantage of the steam motor is its elasticity. The boiler can at a given moment greatly increase production; a tubular boiler does so by the reserve of heat constituted by the volume of hot water under pressure; an instantaneous vaporisation boiler, such as the Serpollet type with thick tubes, does so by the reserve of heat constituted by the bulk of the metal tubes; a Serpollet boiler with water heated by petroleum does so by its very great rapidity of vaporisation. In all the cases the additional power which the boiler gives greatly facilitates travelling over broken ground. The working of the motor itself is very elastic owing to the ease in varying admission of steam. For starting, after the first piston strokes a maximum power can be obtained by taking the notch for slightest expansion, and (if the motor is compound and furnished with a valve which gives direct communication between boiler and large cylinder) by making the large cylinder work at full pressure. When during a journey speed or power has to be varied it suffices to modify expansion. This enables the transmission mechanism to be greatly simplified. As a rule two mechanical changes of speed are considered sufficient, and often there is not even mechanical change, whereas with petrol motors there are three or four. Backward motion is obtained by simply altering the direction in which the steam acts; the car is stopped by shutting off steam and thus stopping the motor, so that during the period of stoppage there is no useless consumption of energy. All these movements, so favourable to good working of the car, are obtained in the easiest way imaginable, by the aid of a valve and reversing lever. Moreover, as the expenditure of steam, and consequently fuel, is at each instant regulated by the power required for propulsion of the vehicle, economic employment of the work furnished by the motor is thus assured. To form an idea of the economy of a steam motor, Marcel Deprez says that daily experience demonstrates that a locomotive boiler consumes 1 kg. of coal per 8 kg. (1 lb. per 8 lb.) of steam. The trials made by the Eastern Railway Company of France demonstrated that the horse-power hour can be obtained at the tyres of the driving wheels after allowing for the loss of force by friction of the mechanism with a consumption of 11 kg. (24·2 lb.) of steam. This is equivalent, remembering that the French horse-power hour represents 270,000 kgm. (1,953,000 ft.-lb.), to a production of about 25,000 kgm. per kg. of steam (82,180 ft.-lb. per lb.). Allowing with Deprez that the boiler of an automobile gives 7 kg. of steam per kg. (7 lb. per 1 lb.) of coal, and that the efficiency of the motor is about one-third less than that of the locomotive, the kg. of steam would then only give 16·5 kgm. (1 lb. would give 54·25 ft.-lb.). Deprez considers that by superheating the steam suitably these figures could be exceeded. Calculating from these figures, and reckoning a traction co-efficient of 0·03 on level ground, it may be ascertained what quantity of coal would run a one-ton car 100 km. (62 miles) with a difference of altitude between the starting and arrival points of 500 m. (547 yards). The work to be developed would amount to 3,500,000 kgm. (25,316,000 ft.-lb.). The amount of steam necessary to give this work would be 212 kg. (466·4 lb.), and the amount of coal to produce this steam 30 kg. (66 lb.), say 300 gr. (0·66 lb.) of coal per kilometre tonne, that is 1·1 lb. of coal per mile-ton. With coal bought retail at the rate of £1 12*s.* per ton this would cost 0·114*d.* per km. (0·62 mile). Allowing that an automobile gives the same economic results as a locomotive, say 8 kg. (17·6 lb.) of steam per kg. (2·2 lb.) of fuel, and 25,000 kgm. (181,000 ft.-lb.) at the wheel tyres per kg. (2·2 lb.) of steam, the consumption falls to 175 g. of coke per kilometre-tonne (9·4 oz. per mile-ton), reckoned at £1 the ton, the cost falls to 0·41*d.* per kilometre-tonne (0·67*d.* per mile-ton), which is certainly little.

The great objection to the steam motor is the necessity of a boiler, which, with the supply of water and fuel, is a considerable weight. It is taken that the boiler, like that of a locomotive, can give 90 kg. (198 lb.) of steam, and weighs 120 kg. per m.^{2} (24·57 lb. per sq. ft.) of heating surface and that the automobile must run 30 km. (18·6 miles) per hour when the gradients do not exceed 3 per cent. To maintain this speed with this maximum declivity, the motor must furnish per second energy equal to 500 kgm. (3,600 ft.-lb.), and the hourly consumption will be about 110 kg. (242 lb.) of steam. For this the heating surface of the boiler should be 1·25 m.^{2} (13·5 sq. ft.), and the weight 1·25 × 120 = 158 kg. (347·6 lb.). As regards supplies, if the automobile has to run 100 km. (62 miles) without replenishing, it must carry 212 kg. (466·4 lb.) of water, and 30 kg. (66 lb.) of coke; total, 242 kg. (532·4 lb.). Thus the boiler and supplies weigh about 400 kg. (800 lb.), say 40 per cent. of that of the car; this is an enormous proportion. Reckoning the weight of a two-cylinder motor as 50 kg. (110 lb.), including valve gear and the weight of two persons, with their light baggage as 200 kg. (440 lb.), there remains a little more than 350 kg. (770 lb.)

for the weight of the vehicle alone. With the more favourable hypothesis admitted in the second place, the weight of the supplies would be reduced to 140 + 17·5, about 160 kg. (352 lb.). If the boiler gave an efficiency equal to that of torpedo-boat boilers, which, with equal heating surface, do not weigh more than 0.6 of the weight of locomotive boilers, it would weigh only 0·6 × 150 = 90 kg. (198 lb.). Thus boiler and supplies, being scarcely 250 kgs. (550 lb.), will only represent one quarter of the weight of the car. If a simple means is found of adding a condensing apparatus the supply of water will be much decreased, as already is the case, especially with some types of Serpollet cars. Besides, more frequent supplies than supposed may be allowed, water being taken in every 50 km. (31 miles) instead of 100 km. (62 miles). Other inconveniences of the coal-fired boiler are: (1) There is difficulty in placing it so that it can be easily tended, and yet not be in the passengers' way. (2) It requires the attendance of a competent stoker. (3) It throws out sparks, smoke, and steam, which may frighten horses and inconvenience pedestrians. The heavy vehicle trials at Versailles in 1897 demonstrated that these inconveniences could be almost suppressed by furnishing the funnel with a grating to prevent the escape of sparks and by superheating the exhaust steam, and mixing it with the hot gases of combustion so as to render it invisible. (4) It requires some time (half an hour) to get up steam. All these inconveniences are much lessened when liquid fuel replaces the coal or coke, as in the majority of modern light cars.

For light touring automobiles propelled by steam, change of fuel is necessary. Many cars use petrol spirit with which storage of considerable energy becomes easier (it gives more than 10,000 calories per kg. (18,026 British heat units per lb.), instead of 8,000 calories (14,420 British heat units) like coke, and can be carried in a vessel whose shape can be made to accommodate available space); with liquid fuel the ordinary advantages of steam exist, a stoker is not needed, the management of the fire is reduced to working a tap, lighting up is instantaneous, and getting up steam pressure rapid. Economy will be increased when heavy crude oils replace the more expensive spirit. There is no doubt that for long distance touring—for which, hitherto, petrol motors seem to have been adopted exclusively—this system of heating will become popular.

The petrol motor has the advantage over steam of giving a greater efficiency, and a greater amount of energy is stored volume for volume and weight for weight than with steam. To run a one-ton automobile for a distance of 100 km. (62 miles) 4·66 kg. (10·25 lb.) of petrol spirit is required, this having a volume of 6·66 l. (11·72 pt.), reckoning the density of the petrol at 0·7. One kg. (2·2 lb.) of petrol spirit corresponds to at least 10,000 calories, or 4,250,000 kgm. (30,740,850 ft.-lb.), which, according to Deprez, represents about 750,000 kgm. (5,425,000 ft.-lb.) available at the wheel tyres. But taking 250,000 kgm. (1,808,300 ft.-lb.) to be the actual work at the tyres per kg. of petrol spirit, the weight of spirit required for the 100 km. will be 13·98 kg. (30·75 lb.), representing at 0·7 density nearly 20 l. (35 pt.). Even reckoning the weight of the petrol reservoir and carburetter, the weight is small in comparison with that required by steam. The total weight of a 6½ h.p. petrol motor with all accessories and supplies may not exceed 200 kg. (440 lb.), whilst a steam motor of equal power would weigh 450 kg. (990 lb.). The enormous difference, even though reduced a little to allow for the weight of the water which cools the motor, remains free for strengthening the carriage work. Another advantage of petrol motors is the comparative ease with which they are started.

The disadvantages of petrol motors, however, are numerous. The chief is the absence of elasticity or adaptability of working. As Soreau remarks, the amount of carburetted air is regulated by the volume of the cylinder, but its richness cannot vary greatly, because the explosion does not occur when the proportions corresponding with complete combustion are exceeded or not attained. The quantity and the richness of the explosive mixture are almost invariable, and it follows that the power cannot be greatly increased.

Moreover, the motor does not give a profitable efficiency, and the power for which it was constructed, unless it revolves at the normal rate of speed. However little it may vary from this, the fuel is wasted partly, and the motor power decreased. For varying the speed and work of the car, between the motor shaft and the driving wheels is placed a system of transmission gear, which absorbs some of the useful power, and complicates the mechanism. In practice it even happens frequently that the dimensions of these parts are calculated badly. For example, when a car climbs a hill at slow speed, its maximum power being required, the motor must not cease to turn at its regular speed. Now, very often the transmission gear is so arranged that the motor cannot preserve its regular speed; this is a real but only too frequent defect of construction. Motive power being due to the combusion of the carburetted mixture, the working is not so smooth as that of a steam motor; the jolts are destructive to the material, and little conducive to uniform motion. Moreover, a heavy fly-wheel is necessary with the petrol motor, and some constructors have a tendency to lighten it; then it is unable to store all the energy which is lost in destructive effects, and the motor is thus found unable to give the work for which it was calculated. The enormous speed at which a petrol motor is run tends to make the quickly running car itself serve as a fly-wheel, and vibrations are much decreased. At low speeds, however, and still more so during stoppages of the car, the vibrations are a great inconvenience. If the motor were stopped always when the car was stopped it would be necessary, when re-starting the motor, to rotate the motor shaft by turning the winch, and this would necessitate the driver leaving his seat. Running of the motor during stoppages of the car involves, of course, sheer loss of petrol spirit. A great inconvenience of the petrol motor is the necessity of cooling the cylinder. Air-cooling answers only when the motive power is not greater than 2 or 3 h.p. (some few constructors consider it possible beyond this); above this power water-cooling must be employed, and for this purpose a considerable and frequently-renewed quantity of water is required.

Another defect is that the driving strain being always produced on the same side of the piston the motor cannot adapt itself to a change of direction; consequently, in order to make a backward movement, use must be made of gearing or pulleys with a crossed belt. These are not found on some vehicles, but in France the Regulations of March 10, 1899, impose them upon all automobiles which empty exceed 250 kg. (550 lb.) in weight. Carburetting, in itself fickle, varies particularly with the humidity and temperature of the outer air, and this often is a source of trouble, especially to the inexperienced. The exhaust gases exhale an odour which, though not noticeable to the passengers, is very unpleasant to people in the wake of the car. Petrol spirit is dangerous to handle, especially when a light has to be used at night, and the tanks and carburetters must be emptied. The cost price of traction is greater than with coke; thus with petrol spirit the 100 km. run with a one-ton car would cost (petrol spirit at 4·3*d.* per l., that is, 2·4*d.* per pt.), either 2*s.* 4½*d.*, or 7*s.* 1½*d.*, either 0·285*d.* or 0·855*d.* per kilometre tonne, that is, either 0·475*d.* or 1·42*d.* per mile-ton, according to which hypothesis is adopted (*see* p. 344). With coke the cost of a kilometre ton is from 0·114*d.* to 0·0418*d.*, and of a mile-ton from 0·19*d.* to 0·069*d.* The above inconveniences are increased very much as the size of the motor increases, and so a limit is placed upon the power of the petrol motor. This seems likely to bar its use for the transport of any load weighing more than 1,500 kg. (3,300 lb., a little less than 1½ tons). This margin, however, allows a town or suburban delivery by automobile instead of by traction engine. The absence of a boiler and the lightness of the motor supplies would deprive the traction engine of weight which is essential to it to obtain sufficient adhesion. On the other hand, the advantages of carrying considerable energy, of easily obtaining supplies on the road, and that one person can both drive and attend to the car, make the petrol automobile the indispensable agent for long-distance touring. Recommendations of petroleum in the place of petrol spirit are its lower inflammability, this decreasing dangers of conflagration, and its cheaper cost. Petrol spirit gives off inflammable vapours at 5° C., often at 0° C., whilst petroleum can be heated to 35° C. without igniting, even when a lighted match is held near. As regards economy, allowing with Witz that 0·57 l. (1 pt.) of petrol spirit and 0·54 l. (0·95 pt.) of petroleum respectively give the effective horse-power hour, and reckoning the former at 4·27*d.* per l. (2·43*d.* per pt.), and the latter at 2·28*d.* per l. (1·3*d.* per pt.), it follows that the horse-power hour with petrol spirit costs 2·47*d.* and with petroleum 1·235*d.*, exactly half. The difficulties of carburetting petroleum are not insurmountable, and already some automobiles, the Roots for example, are driven with petroleum.

With regard to the electric automobile, the continuity of rotary motion, its elasticity, and what is practically automatic regulation, give superiority to the electric motor. It is managed easily, is docile, has a noiseless motion, and the motor itself is mounted in a very simple manner. Over petrol cars it has the advantages of easier starting, greater cleanliness, and perhaps lower cost of upkeep.

There is but little vibration with the electric automobile, no bad odour, and no consumption of energy whilst the car is stopped. It is not claimed that electric cars will not burn, because it is possible for the celluloid of the accumulator cases to be ignited by a short circuit; but all serious risk of fire can be avoided by replacing celluloid with ebonite, though this adds slightly to the weight.

The inconveniences of electricity as automobile motive power are increase of dead weight carried, maintenance and renewal of accumulators of uncertain duration, difficulty of obtaining supplies for the accumulators, and the loss of time in charging. These inconveniences are lessened greatly in cars for town work.

The part assigned to each of the three principal agents is, then, in brief, steam for heavy loads, petrol for long-distance touring, and electricity for town cars. This statement must not be taken too literally, because the light steam touring car has proved its worth of late, and on the other hand the Milnes and some French and German petrol lurries promise to rival the heavy steam car. Besides, the general remarks hitherto made must be brought to bear, especially as regards facilities for obtaining new supplies of energy. There is now no difficulty in obtaining petroleum and petrol spirit, but electric supplies are not so easily got, unless the house has a suitable installation. As regards rapidity of starting, the order is electric, petrol, and steam.

The petrol-electric car has not been considered in this chapter, and it is difficult to give it its place in relation to the other types. Experience and comparative tests are lacking, and there seem to be no published figures from which any helpful conclusions can be drawn. However, admitting that of the three types just considered the best all-round car is the one driven by petrol, and that this is likely to be so until the electric car has progressed out of all proportion to the rate of its development hitherto, it certainly seems that there is a big future before the petrol-electric car. The system is fully explained in Chapter XX. (p. 731), and its peculiarities cannot be gone into here; briefly, it is a petrol car with an electrical transmission and a reserve of electrical power, and apparently it is as suitable for heavy loads as it is for long distance touring, and whilst not as well adapted for town use as the purely electrical car, it certainly has advantages over petrol in that respect, and over electricity and steam for touring.

CHAPTER X.

TRACTION RESISTANCES: DETERMINING MOTOR POWER REQUIRED BY AN AUTOMOBILE.

In calculating the power necessary to make an automobile run at a required speed, it is first necessary to know the useful effort which will have to be developed at the tyres of the driving wheels. This effort will be determined by the resistance of the vehicle to traction.

This chapter embodies all the important facts concerning traction resistances put forward in the first edition of this work, but in the present form as regards the first nine pages it is an abstract from a report prepared by Prof. H. S. Hele-Shaw, and presented at the 1902 meeting of the British Association for the Advancement of Science. It ,summarises the results obtained by most of the English and French observers.

It may be remarked that observations and experiments by MM. Corréze and Manes showed that the resistance to rolling is composed of two elements: (1) Friction of the wheel upon the road; (2) axle friction. Regarding (1), that wheels of vehicles destroy the road in proportion to their load, width of tyres, and speed. If the tyres be narrow the friction may be simply treated as a rolling friction, but if the tyre be wide then a pivoting action is introduced. The effect which a wheel produces on the road depends upon the load upon the wheel, the resistance of the material of which the road is made, and on the nature of the surface. If the load be great and the tyres narrow, the wheel will form a rut in the road, but if the tyre be wide the load becomes distributed and does not damage the roadway. MM. Corréze and Manes proved, by direct experiment, that the ratio between the tractive effort and the load increases with the speed. Carriages with four wheels in unequal pairs require less tractive effort than those with two wheels or two equal pairs of wheels.

Coriolis (1835) drew the following conclusions:—That to reduce the work due to resistance the road ought to have as great a rigidity as possible, and that the springs should be as flexible as possible.

Experiments were made by General Morin, 1837-42. The results have been collected together into a large treatise, from which the following is taken:—(*a*) There is the simple turning of one curve on another when the two curved surfaces are always in contact, and when the arcs passed through in a given time are of equal length.

(*b*) Simple rotation of a cylinder on a horizontal surface, when the surface formed on the plane is an envelopment of the cylinder. A cylindrical body alone can roll on a plane in a straight line. If the body be not cylindrical, the rolling motion is accompanied by sliding, or, what amounts to the same thing, pivoting. Thus a wheel with a cylindrical tyre, when rounding a curve, is subjected to simple rotation and also a pivoting action about its vertical axis, and consequently tends to twist from its true position. Calling R the resistance due to friction, which is supposed to act tangentially to the wheel of which r is the radius, p the pressure transmitted by the wheel to its supports, and A a constant; then $R = A\frac{p}{r}$, which sums up the law for rolling friction. Morin experimented to ascertain the truth of this law, and drew the following conclusions:—(1) On fibrous materials, such as wood; on spongy textures, as leathers; on granular bodies, as plaster: "That the resistance to rolling varies inversely as the diameter of the wheel, measuring this force (R) at the circumference of the wheel. (2) On compressible surfaces: "That the resistance to rolling increases as the width of the tyre diminishes." (3) On an elastic substance, such as indiarubber: "That the depth of the depression is practically proportional to the pressure, provided that the elasticity remains constant; the depth of the depressions increases as the width of the tyre diminishes." On a homogeneous body, such as wood: "That the pressure alters the elasticity, and that the resistance to rolling increases more rapidly as the pressure increases; consequently wood pavements are not suitable for heavy traffic." The law quoted is not a general or mathematical law, but only approximately true for certain cases. The causes that have an effect on the tractive effort and also tend to destroy the roads are:—(1) The weight or pressure on the ground; (2) the diameter of the wheels; (3) the width of the tyres; (4) the velocity of the vehicle; (5) the angle of inclination of the pull; and (6) the efficiency of the springs.

The following table gives the results (after General Morin) of the relation between the tractive effort and the total load for different kinds of roads and vehicles:—

Description of State of Roads.	Artillery Waggons.	Goods Waggons.	Carts.	Coaches and Carriages with Springs.	
Turf softened by melting snow	$\frac{1}{8}$	—	—	—	
Turf firm	$\frac{1}{20}$	—	—	—	
Turf very dry	$\frac{1}{24}$	—	—	—	
Earthways in good condition, dry, etc.	$\frac{1}{30}$	$\frac{1}{27}$	$\frac{1}{40}$	$\frac{1}{26}$	
Earth road, covered with untrodden snow	$\frac{1}{16}$	$\frac{1}{15}$	$\frac{1}{21}$	$\frac{1}{15}$	
Firm earth with a bed of sand or gravel ·1 to ·15 m. thick	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{12}$	$\frac{1}{7}$	
Macadam, dry and uniform ...	$\frac{1}{54}$	$\frac{1}{50}$ to $\frac{1}{58}$	$\frac{1}{66}$ to $\frac{1}{82}$	$\frac{1}{57}$ walking.	$\frac{1}{40}$ trotting.
Macadam, wet and dusty, projecting stones	$\frac{1}{38}$	$\frac{1}{35}$ to $\frac{1}{41}$	$\frac{1}{47}$ to $\frac{1}{58}$	$\frac{1}{33}$,,	$\frac{1}{26}$,,
Macadam, firm, slight wear, and soft mud	$\frac{1}{30}$	$\frac{1}{27}$ to $\frac{1}{37}$	$\frac{1}{38}$ to $\frac{1}{45}$	$\frac{1}{26}$,,	$\frac{1}{20}$,,
Macadam, firm, with ruts and very muddy...	$\frac{1}{24}$	$\frac{1}{22}$ to $\frac{1}{25}$	$\frac{1}{20}$ to $\frac{1}{36}$	$\frac{1}{21}$,,	$\frac{1}{17}$,,
Macadam, worn and covered with thick mud	$\frac{1}{20}$	$\frac{1}{18}$ to $\frac{1}{21}$	$\frac{1}{25}$ to $\frac{1}{31}$	$\frac{1}{18}$,,	$\frac{1}{15}$,,
Macadam, badly worn and rutty, mud very thick ...	$\frac{1}{16}$	$\frac{1}{14}$ to $\frac{1}{16}$	$\frac{1}{19}$ to $\frac{1}{25}$	$\frac{1}{15}$,,	$\frac{1}{11}$,,
Macadam, very badly worn, and with deep ruts, hard foundation, and unequal surface	$\frac{1}{14}$	$\frac{1}{12}$ to $\frac{1}{15}$	$\frac{1}{17}$ to $\frac{1}{21}$	$\frac{1}{12}$,,	$\frac{1}{10}$,,
Sandstone roads, well set, and closely laid	$\frac{1}{70}$	$\frac{1}{64}$ to $\frac{1}{74}$	$\frac{1}{80}$ to $\frac{1}{107}$	$\frac{1}{62}$,,	$\frac{1}{35}$ full jog.
Paved roads, wet, and covered with mud	$\frac{1}{50}$	$\frac{1}{46}$ to $\frac{1}{55}$	$\frac{1}{61}$ to $\frac{1}{78}$	$\frac{1}{44}$,,	$\frac{1}{35}$ trotting.
Timber flooring of a bridge...	$\frac{1}{46}$	$\frac{1}{42}$ to $\frac{1}{49}$	$\frac{1}{71}$	$\frac{1}{41}$,,	$\frac{1}{41}$,,

Dupuit, however, pointed out a number of errors in Morin's calculations, and concluded from his own experiments that on uniform surfaces generally, as macadam, the tractive effort is (1) proportional to the load; (2) independent of the width of tyres; (3) inversely proportional to the square root of the diameter of the wheels; and (4) independent of the velocity. Further, that the tractive effort or horizontal force necessary to move a vehicle on the level is expressed by the formula $T = \rho\frac{\sqrt{2R}}{P}$, where P = weight of vehicle; R = resistance to rolling; and ρ = a constant which expresses a ratio between the compressibility and elasticity of the surface, so that $\rho = \frac{3}{8}\frac{\epsilon}{\sqrt{\epsilon^1}}$, in which ϵ is the instant compression of the ground, and ϵ^1 the permanent set due to the load. On paved roads Dupuit recognised that the formula had to be modified, for although the force required is always proportional to the load and to the square root of the diameter of the wheels, yet it increases with the speed, and diminishes as the width of tyre diminishes within certain limits, and also that springs diminish the force required, whereas on macadam springs have very little influence. Dupuit's table for the ratio of tractive force to load is as follows:—

Class of Vehicle.	Diameter of Wheels.	Width of Tyres in Metres.	Ratio of Tractive Force to Pressure on		
			Macadam, Walking or Trotting.	Paved Roads.	
				Walking.	Trotting.
Cart	1·82	·05	·032	·012	·028
Rubbish cart	1·85	·075	·031	·0205	·028
" "	1·89	·11	·03	·0176	·028
" "	1·90	·14	·03	·0166	·028
Gig	1·48	·05	·036	·024	·034
Carriage	1·96	·17	·029	·0177	·028
Char-à-banc	1·50	·05	·036	·03	·037
" "	0·86	·05	·036	·03	·037
Coach	1·5	·13	·029	·016	·02
"	0·95	·13	·029	·016	·02

Dupuit found that the mean force required to draw a vehicle loaded up to 1,000 kg. (2,200 lb.) was on macadam roads = 30 kg. (66 lb.), on paved roads = 20 kg. (44 lb.); that on flagstones perfectly dressed the tractive force required equals 6 kg. (13·2 lb.) per ton, and that on asphalt the tractive force equals about 10 kg. (22 lb.) per ton. From these he obtained the following ratio:—The resistances on railroads, pavements, and macadam are as 1, 4, and 6; but these resistances are not in proportion to the respective roughnesses, which are as 1, 15, and 36. Dupuit found that the edges of tyres became furrowed into deep grooves, and that some particles of the stretched iron became detached. He concluded that the length of contact of a tyre is of more importance than the width, and that wide tyres are only useful when they bear on the road throughout their whole width, and in cases when the road is soft, uneven, and in a bad condition. Moreover, since the tyre is rounded, the pressure is unequal throughout its whole width, and not only does it diminish on both sides of the centre, but to the right and left, the surface in contact forming an ellipse the major axis of which increases far more rapidly with the diameter of the tyre than the minor axis increases with the width of tyre. Dupuit further concluded that 4,000 kg. (8,800 lb.) might be taken as a standard load for a two-wheel vehicle, and the weighting distributed as follows: Wheels (one pair), 600 kg. (1,320 lb.); axle and frame, 520 kg. (1,146 lb.); useful load, 2,880 kg. (6,350 lb.). From experiments Dupuit concluded that, providing the road had no very sudden rises or depressions, the effect of the undulations was practically nil.

Edmund Leahy, C.E. (1847) states that the power required to move a car on a level road depends upon the friction of the axles and the resistance to rolling. The friction of the axles is the same in nearly all cases, as long as the load and the car are the same; but the resistance to rolling, having its immediate action at the tyre, must be variable according to the description of road on which the wheels move. He proves that the friction at the axle can be represented by the following formula:—

$$P = W \frac{d}{2r} \tan A,$$

where P is that force applied at the tyre which is just sufficient to rotate the wheel when supported on its axle, where W is the load on the axle, d the diameter of the axle, $2r$ the diameter of the wheel, and A is the limiting angle of resistance for the surfaces in contact.

Coming to more modern and more representative experiments, A. Michelin (1896) made a series of five tests, the general data being:— Diameter of iron wheels, front 0·92 m. (36·2 in.), back 1·12 m. (44·1 in.); diameter of pneumatic wheels, front 0·90 m. (35·4 in.), back, 1·20 m. (47·25 in.); weight of iron wheels, front 58 kg. (127·8 lb.): back 72 kg. (158·7 lb.); weight of pneumatic wheels, front 39 kg. (86 lb.), back 56 kg. (123·4 lb.); weight of brake, empty, iron wheels, 577 kg. (1 272 lb.), and weight of brake, empty, pneumatic wheels, 542 kg. (1,195 lb.). He found that even upon hard and smooth ground pneumatic tyres gave a greater economy, amounting to about one-third. Experiments were made on a good regular macadam road; length 100 m. (328 ft.), grade 1·5 per cent. Each test was repeated several times with an empty vehicle, from which were deduced the following average speeds:—For pneumatics, 4·900 km. (3 miles) per hour = walking speed; 10·5 km. (6·5 miles) = trotting; and 15·12 km. (9·4 miles) = quick trot. For iron, 4·550 km. (2·82 miles) per hour = walking speed; 10·94 km. (6·8 miles) = trotting; and 15·12 km. (9·4 miles) = quick trot. The averages of the forces exerted are shown in the following table:—

	Walking.	Trotting.	Quick Trotting.
For pneumatics	13·0 kg.	13·5 kg.	13·5 kg.
For iron wheels	13·8 kg.	17·0 kg.	22·1 kg.

It will be noticed that at the trot and quick trot the results for pneumatics are the same. It appears, then, that whatever the speed may be within reasonable limits, the force absorbed by traction varies but little on good ground with pneumatic tyres. Then the advantage of the pneumatic over the iron tyres increases with the speed. With 100 as the pneumatic traction, the iron traction at the ordinary trot is 126, and at quick trot 164. The following conclusions can be drawn from the experiments:—(1) The solid indiarubber tyre is better than the iron in certain cases, especially if the road be sticky, very irregular, or covered with snow; but it becomes inferior to iron if the surface be hard and smooth. (2) Solid tyre vastly inferior to the pneumatic. (3) Pneumatic 50 per cent. better than the iron.

Prof. Hele-Shaw made a number of experiments in 1897, and obtained the tractive force for agricultural waggons and carts on turf and roads. The table on p. 354 is a brief summary of the results.

According to the investigations of Ira O. Baker, M.Am.Soc.C.E. (1902), the resistance to traction of a vehicle on the road consists of three independent elements:—(1) Axle friction; (2) rolling resistance; and (3) grade resistance. Nothing need here be said about grade resistance, since it is perfectly understood that it is equal to 20 lb. per ton for 1 per cent. of grade.

1. *Axle Friction.*—The coefficient of friction varies with the material of the journal and its bearings, and with the lubricant. It is nearly independent of the velocity, and according to the author's experiments seems to vary inversely as the pressure. Compared to the weight on the axle, the coefficient for light carriages when loaded

	Diameter of Wheels. Inches.		Width of Tyres. Inches.		Weight of Waggon or Cart. Lb.	Load in Tons.	Tractive Force per Ton of Load on Turf.	Tractive Force per Ton of Load on Road.
	Fore.	Hind.	Fore.	Hind.				
Waggons...	39	42	4	4	2,142	3	235	148
,, ...	39	42	4	4	1,895	3	277	125
,, ...	37	41	4	4	1,813	3	289	139
,, ...	36	40	4	4	1,752	3	227	170
Carts ...	65	—	3	—	1,281	1½	269	116
,, ...	60	—	4¾	—	1,435	1½	260	147
,, ...	59	—	4½	—	1,235	1½	232	111
,, ...	59	—	4½	—	1,278	1½	240	109
,, ...	58	—	4	—	1,333	1½	253	130
,, ...	57	—	4½	—	1,379	1½	248	153
,, ...	56	—	4	—	1,148	1½	235	108

= 0·02; for heavier carriages when loaded = 0·015; for American thimble skein waggon = 0·012. The above figures assume good lubrication. If there is a deficiency of lubricant, these figures are two to six times greater. General Morin's value for axle friction was 0·065; this difference is probably due to the better mechanical construction of the present day. The tractive force required to overcome the axle friction is about 3 to 3½ lb. per ton of the weight on the axle for ordinary waggons, and from 3½ to 4½ lb. for waggons with medium-sized wheels and axles.

2. *Rolling Resistance.*—The resistance of a wheel to rolling is due to the yielding or indentation of the road, which causes the wheel to be continually climbing an inclination. The resistance is measured by a horizontal force necessary at the axle to lift it over the obstacle, or to roll it up the inclined surface. The rolling resistance varies with (*a*) the diameter of the wheel; (*b*) the width of the tyre; (*c*) the speed; (*d*) the presence or absence of springs on the vehicle; (*e*) the nature of the road surface.

a. The Diameter of the Wheel.—The rolling resistance varies inversely as some function of the diameter of the wheel, since the larger the wheel the less the force required to pull it over the obstacle. The results of the experiments are shown in the first table on p. 355, the load being 1¾ ton of 2,000 lb. per ton, with tyres 6 in. wide.

Morin concluded that the resistance varies inversely as the first power of the diameter of the wheel; Dupuit that it varies inversely

Description of the Road Surface.	Tractive Force, lb. per Ton.		
	Mean Diameter of Front and Rear Wheels.		
	50 in.	38 in.	26 in.
Macadam, slightly worn, clear fair condition	57	61	70
Gravel road, dry, sand 1 in. deep, loose stones	84	90	110
„ up grade 2·2 per cent., ½ in. wet sand, frozen below	123	132	173
Earth road, dry and hard	69	75	79
„ „ ½ in. sticky mud, frozen hard below, rough	101	119	139
Timothy and bluegrass sod, dry, grass cut	132	145	179
„ „ „ wet, spongy	173	203	281
Cornfield: flat culture; across rows, dry	178	201	265
Ploughed ground; not harrowed, dry, cloddy	252	303	374
Average value of the tractive power ...	130	148	186

as the square root; Clark that it varies inversely as the cube root; and Baker that it varies very nearly inversely as the square root of the mean diameter.

b. Width of Tyres.—If the wheel cuts into the road, the traction is thereby increased; but for surfaces where there is little or no indentation the width of tyre has practically no effect upon the traction; see the table below.

EFFECT OF THE WIDTH OF TYRES ON TRACTION.

Description of the Road Surface.	Resistance to Traction in lb. per Ton of 2,000 lb.									
	44 in. and 46 in. Wheels.				44. in. and 54 in.		42 in. and 46 in.		44 in. and 54 in.	
	Tyres.				Tyres.		Tyres.		Tyres.	
	1½ in.	4 in.	1½ in.	4 in.	1½ in.	4 in.	1¼ in.	3 in	1¾ in.	3 in.
Sod	—	—	—	—	—	—	283	239	189	228
Roads: earth hard	—	108	—	—	—	—	152	152	114	114
„ „ muddy ...	—	243	268	304	236	254	—	—	265	228
Sand: hard	199	162	171	164	141	168	—	—	—	—
„ deep	371	351	—	—	—	—	—	—	—	—
Gravel	—	—	98	117	83	80	—	—	66	76
Wood block: round ...	51	49	61	70	35	46		54	28	38

c. Effect of Speed.—The rolling resistance increases with the velocity, owing to the effect of the shocks or concussions produced by the irregularities of the road surface. It requires from two to six or eight times as much force to start a vehicle as to keep it in motion at 1·24 to 1·86 km. (2 to 3 miles) an hour. The extra force required is due to:—

(1) During the stop the vehicle has partly sunk into the road.
(2) Axle friction is greater at starting than after motion has begun.
(3) Energy is consumed in accelerating the load.

d. Effect of Springs.—Springs decrease the traction by decreasing the concussions due to the irregularities of the ground, and are therefore more effective at high speeds than low, and on rough roads than on smooth.

e. Different Road Surfaces.—The tractive force was obtained by a Baldwin dynagraph. The instrument consists of two long flat springs fastened together at their ends, and having their centres farther apart than their ends. One end of the apparatus is attached to the waggon, and the other to the team. The pull of the team causes the centres of the flat springs to approach each other. One spring supports a graduated disc, and the other is connected to an index arm which is pivoted at the centre of the graduated disc. From one end of this index arm the pull can be read directly from the graduation. There are two extra index arms, one to indicate the maximum power developed, and the other to indicate a rough average. The end of the index arm, opposite the graduated arc, records the amount of traction upon a strip of paper which is wound from one cylinder to another by clockwork; see the table on p. 357.

This maximum strain at the wheel tyres is less than that which the motor must develop, because losses during transmission to the wheel tyres must be reckoned. With steam motors and petrol motors it is well to estimate these losses at 40 to 50 per cent. respectively (pp. 807 and 808), which gives 60 and 50 per cent. for the efficiency of the transmission gear. Then the value found for the motor strain must be multiplied by $\frac{5}{3}$ or by 2, accordingly. The simple transmission gear used with an electric motor greatly decreases the losses of energy between the motor shaft and tyres. In calculating the energy to be supplied by accumulators (Chap. VIII.), Hospitalier's estimate of 90 per cent. as efficiency of the transmission gear was taken, but this is too great in those cases where

TRACTIVE RESISTANCE OF LEVEL PAVEMENTS.

Description of Pavement.	Lb. per ton 2,000 lb.
Asphalt: clean, smooth, no cracks, 52° F.	37
" " " " 84° F.	70
" " " " 42° F.	34
Brick: 3 in. by 9 in. bricks on concrete, corners rounded, sand filler, not worn ...	17
" " " " but newer and covered with ⅛ in. dust ...	31
" " " " but cement filler, just completed ...	22
" 2¼ in. by 8 in. brick on concrete, pitch filler; new	24
" 3 in. by 8 in. brick on gravel and cinders; sand filler, corners not round...	37
" 2¼ in. by 8 in brick on sand and old macadam, tar filler; new	25
Granite block: smoothly dressed 3 in. by 9 in. blocks on concrete joints, ¼ in. tar filler; not worn	29
" smoothly dressed, on concrete, pitch filler; new	30
" ordinary granite, ten years' wear	36
Macadam: granite top, no dust, no mud	18
Plank road: oak plank, 3 in. by 12 in.; nearly new	32
" same as above, after worn down ¼ in. in many places; clean ...	38
" as above, covered with ¼ in. fine loose dirt	40
Steel wheelway: 8 in. 11¼ lb. channel, on 2 in. by 8 in. pine, on macadam; covered with ⅛ in. powdered stone	40
" " same as above, scraped clean with a shovel	19
" " " " covered with ⅛ in. fine dust	28
Wood block: rectangular blocks, 3 in. by 12 in., considerably worn	36
" " round cedar block, covered with ½ in. silica pea gravel	90
" " " " " " " ¼ in. crushed gravel	50
" " " " " clean, blocks slightly convex on top	53
" " round cedar block, 2 in. plank, 2 in. sand, clean, not worn ...	37
" " same as above, clean, slightly worn	51
" " " " " considerably worn	54

there is not a motor mounted on each wheel, because the losses of pressure caused by the differential gear and chain must be reckoned. Taking Morris and Salom's value of 70 per cent. for the efficiency of this transmission, it suffices to multiply the useful motor strain by $\frac{10}{7}$ to obtain the power normally to be developed by an electric motor. The method just sketched for estimating the motive power required is logical, but is not always employed. It would have the advantage of proportioning the force of the car to the work expected, and preventing very serious miscalculations.

Whatever the method employed to estimate the power to be given to a motor, the resulting horse-power will always exceed that of the horses which would have to be yoked to the car in question, even reckoning the increase of weight due to the motor mechanism. Even though a horse can give a power of only 50 kgm. (362 ft.-lb.) per second during six hours per day, whereas a 1 h.p. motor can supply, during 24 hours, its 75 kgm. (542·5 ft.-lb.) per second, a total of 6,480,000 kgm. (46,870,000 ft.-lb.), or six times more than the 1,080,000 kgm. (7,812,000 ft.-lb.) given by a horse; it must be remembered that a horse can easily double its muscular power for some considerable length of time, and at a difficult passage, quintuple and even increase it tenfold, whilst the mechanical motor, especially the petrol type, is far from possessing such elasticity. Thus it is necessary to give the mechanical motor a maximum power far greater than it will regularly be required to develop. Consequently from 6 h.p. to 40 h.p., and even more, have become ordinary powers for carriages which need hardly 2 or 3 horses to haul them. When they succeed in utilising all this power, it is not to be wondered at that they attain enormous speeds, far outdistancing traction by horses.

Having suggested how to estimate the power of the motor with which a car is to be furnished to make it capable of giving a certain speed under certain conditions, it remains to be shown how to determine the power of a motor actually mounted on an automobile. The work it gives on the shaft and that developed at the tyre of the driving wheels must be measured. Several methods are applicable to determine the available power on the shaft; by the first it is calculated by basing on theoretic or empiric data, and by the second it is measured by submitting the motor to certain tests.

Ringelmann estimates that combustion of one gramme of petrol spirit (0·035 oz.) requires 16·3 l. (28·7 pt.) of air, practically. If V represents the volume in litres of a cylinder, the weight in grammes of petrol consumed to fill the cylinder with carburetted air will be $\frac{V}{16 \cdot 3} = 0 \cdot 06135\ V$. Let n be the number of revolutions of the motor per minute, supposing it to be a four-cycle motor, it will give 0·50 n explosions per minute. Ringelmann admits that to avoid excessive heating there is only 0·45 n per minute, and thus $\frac{0 \cdot 45n}{60} = 0 \cdot 0075\ n$ per second. The weight of petrol spirit in grammes consumed per second will therefore be $0 \cdot 06135\ V \times 0 \cdot 0075\ n = 0 \cdot 00046\ n\ V$. Theoretically, each gramme of petrol spirit is equivalent to 11 calories (43·6 B.H.U.). Ringelmann admits that in these 11 calories 0·15 × 11, only = 1·65 (6·53 B.H.U.) are effectively transformed into work. In other words, 0·15 is the thermal efficiency (p. 807). Therefore, the power obtained is only 1·65 × 425 = about 700 kgm. (5,060 ft.-lb.); consequently the motor power is in h.p.

$$P = \frac{700 \times 0{\cdot}00046}{75} n V = 0{\cdot}0043 \, n V.$$

Employment of this formula only requires the dimensions of the cylinder and the number of revolutions of the motor per second.

The Witz method is as follows:—Given the average pressure $p\,m$ exerted by the explosion of the charge on the piston during its driving stroke, and the organic efficiency K of the motor, S being the section of the piston and C its stroke, n the number of revolutions per minute, and P the effective work in h.p., the formula is $K \frac{S\,C\,p\,m\,n}{2 \times 60 \times 75} = \frac{K\,S\,C\,n\,p\,m}{9{,}000}$. K, the motor efficiency, can be taken as equal to 0·75, whilst $p\,m$ is estimated by Witz as 4·25 kg. (9·35 lb.). Applied by him to three motors, this method gave a slightly less power than that stated by the constructors.

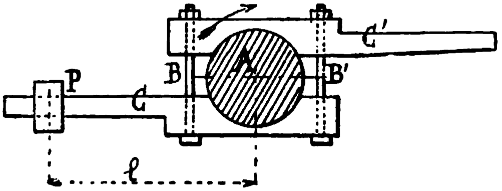


Fig. 352.—Prony Brake Test.

The power may be calculated according to empiric data. Hospitalier says that in studying the principal elements of construction and the working of a certain number of petrol motors, and comparing certain specific factors which theoretically would be identical for motors working in the same circumstances as regards richness of mixture, compression, ignition, and efficiency, it was observed that one of these specific factors was constant at about 20 per cent., in spite of the difference of proportion of system, ignition, and power. This factor is the proportion of the displacement of the cylinders (in litres per second) to the power of the motor (in poncelets), and it is noticeably equal to 10 (a poncelet represents the expenditure of energy equal to 100 kgm. (723 ft.-lb.) per second). It suffices, then, to reckon this displacement in litres per second, multiplying double the volume of the cylinder by the number of revolutions per second, and dividing by 10 to obtain the power in poncelets.

The poncelet is equal to 100 kgm. (723 ft.-lb.) per second, whilst the horse-power is only 75 kgm. (542·5 ft.-lb.) per second; the number found must be divided by 0·75 to obtain the horse-power. Calling n the number of revolutions per minute, R the radius of the cylinder, C its stroke in cm., the following formula may be applied:

$$P = \frac{1}{0{\cdot}75} \times \frac{\pi R^2}{100} \times \frac{2C}{10} \times \frac{n}{60} \times \frac{1}{10},$$ or very approximately

$$P = \frac{nR^2 C}{75{,}000}$$ This formula gives the power with a probable error of one-fifth. The methods of calculation described have the advantage of needing only some dimensions of the cylinder and the number of revolutions of the motor, but owing to the uncertainty of the accepted values for the co-efficients which figure there they are not fully reliable. For estimating motor power more rapidly, the motor must be subjected to a regular test, which can be done in various ways.

Brake tests first will be described. The principle of the well-known Prony brake consists in causing the motor shaft A (Fig. 352) to revolve inside two jaws, tightened on it by bolts B B^1, and loading a lever, G, forming one with these jaws, with a weight, P, sufficient to prevent the jaws being carried round by the rotating shaft: the h.p. is given by the formula $P = 0{\cdot}0014\, p\, l\, n$, p being expressed in kg., l the distance in metres of the point of application of the weight P from axis of the shaft, and n the number of revolutions per minute. The distance l is indicated in Fig. 352. To make a practical test, the motor must first be fixed firmly, such as by screwing down to a wooden frame. Instead of the wooden jaws shown in Fig. 352, a flat iron band is often employed, furnished with hard wood cleats, and fixed to the lever on one side by a fixed bolt and on the other by a bolt which can be screwed to variable degrees of pressure. The band generally surrounds the fly-wheel of the shaft, and must be placed as in Fig. 352, the lever being below the horizontal diameter of the pulley, so as to ensure that the indication given by the weight lifted is correct. With the arrangement in which the weighted bar is above, as G^1, Fig. 352, when the lever deviates from the horizontal in a marked manner, the indication may be very inaccurate. To obtain during the experiments constant friction, it is often necessary to adjust the tightness of the bolts. Jolts can be decreased by placing indiarubber washers under the nuts, these washers being separated by sheet-iron discs. As jolts can never be surely avoided, it is prudent to employ catches which, if necessary, can stop the lever. To guard against the brake seizing, it is essential to lubricate it continually with tallow, or with water containing about 10 per cent. of soap. To be conclusive a heat should last ten minutes. The formula given applies to a brake maintaining itself in equilibrium on the horizontal edge of a knife situated in the plane of the axis of the motor shaft. If to establish this equilibrium it was necessary to place a weight p^1 at the other end of the lever, this weight p^1 would have to be deducted from the value of p in the formula. The Prony brake is the usual method of measuring the power of a steam-engine, but it is not suitable for a petrol motor, where the sudden variations of work demand concomitant variation of tightening the brake, which is impossible. Ringelmann has invented a brake which automatically regulates this tightening, and its application to petrol motors is relatively easy, but the cord brake is simpler.

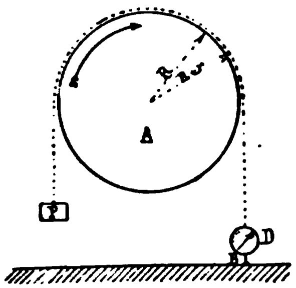


Fig. 353.

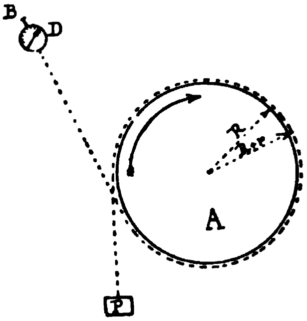


Fig. 354.

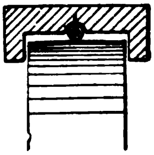


Fig. 355.

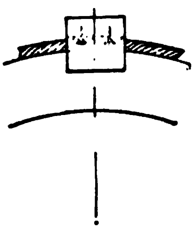


Fig. 356.

Figs. 353 to 356.—Cord Brake Test.

In the cord brake (Figs. 353 to 356) a cord passes round the motor fly-wheel A, one end being fastened to a fixed point B by means of the dynamometer D, the other end supporting the weight P; the dynamometer facilitates regulation by giving the cord a tension

p^1, which is varied by means of a double action tightening screw. The formula applied is $P = \frac{2\pi(R + r)n}{60 \times 75}(p - p^1)$, in which R, r, are radii of the pulley and of the cord expressed in metres, p and p^1 in kg., and n the number of revolutions per minute. For a motor which does not exceed 8 h.p. a cord of from 5 mm. to 6 mm. (0·196 in. to 0·236 in.) in diameter suffices, and a pulley from 20 cm. to 30 cm. (7·87 in. to 11·8 in.) in diameter for 1,700 revolutions per minute. It is only exceptionally that a few drops of soapy water or a little plumbago must be applied to the cord, continuous lubrication not being necessary. The blocks (*see* Figs. 355 and 356) used are not intended to produce friction, their purpose being to keep the rope from spreading and going off the edge of the pulley.

In determining the power of a motor by an electric test, the use of a dynamo is convenient; this having a known efficiency R, it suffices to yoke the motor with it, and note the number of volts E and ampères I recorded by a voltmeter and ampèremeter placed in the circuit of this dynamo to deduce the power in horse-power of the formula P = 736 E I R. For great accuracy the test can be continued for a long time, and this is not always easy to do with the Prony brake, owing to heating. The process is especially applicable for a constructor who successively yokes the various motors to be tested with his dynamo; however, it is more expensive than the preceding.

To ascertain the power available at the wheel tyres of an automobile, the work given by the motor on its shaft must be multiplied by the efficiency of the transmission gear between this shaft and the driving wheels. The efficiency, on an average, is equivalent to 50, 60, or 70 per cent., according as it refers to a motor driven by petrol, steam, or electricity, but the uncertainty of this value affects the result found.

A direct test can be made easily after measuring in kg. the weight p of the car, passengers included; it is driven up a gradient. the inclination I of which is known in cm. and the length L in metres, N being the number of seconds required to make the ascent, and T being the co-efficient of traction in hundredths; then the horse-power is given by the formula: $P = \frac{p\,L\,(I + T)}{75\,N}$

CHAPTER XI.

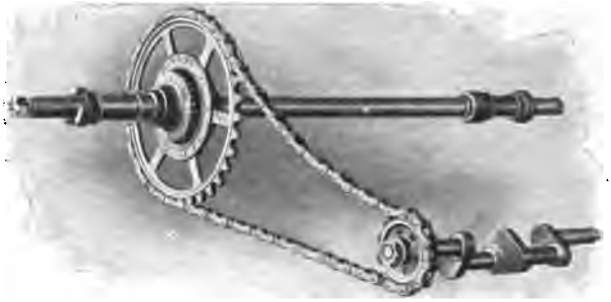
TRANSMISSION OF MOTOR POWER TO DRIVING WHEELS.

TRANSMISSION of power from motor to road wheels is accomplished by a variety of methods, of which the chief will be discussed in this chapter. An automobile has to have more than one rate of speed, and it is quite obvious that it cannot be run at one uniform speed. The electric motor has a somewhat great innate elasticity to meet its many needs, and even the steam motor might suffice strictly, though often it is assisted by mechanical speed-changing gears; but the petrol motor can change speed only by modifying its power, always to the detriment of its efficiency, and thus a speed-changing device is essential with it.

An automobile must be capabla of reversing, that is, running backward. Electric and steam motors enable backward motion by simply reversing the controller or valve gear, but the petrol motor does not admit of reversal, and a mechanical device has to be employed for this purpose.

It must be possible to disengage the motor from the transmission gear. For abruptly stopping a car and making it answer the brake the propelling action must be stopped instantly. When this cannot be done by reversing the motion, which is the case with petrol motors, the motor must be thrown out of gear. This is done also when it is required to run down-hill at great speed, the car being carried along by gravitation; for if motor and wheels are left connected the latter cannot exceed the speed of the first, and there is great risk of overrunning the motor and injuring some of the mechanism. During the frequent short stoppages to which an automobile is liable the petrol motor must not be allowed to cease work, or there will be the trouble of restarting. Here, again, a device for throwing the motor out of gear is necessary. Progressive gear greatly facilitates starting.

The independence of the driving wheels in turning with regard to each other is another essential. If each wheel is not driven by a separate motor, the two wheels on one axle must not be so fixed that they always turn together. The differential gear usually gives this independence, and this is described later (*see* pp. 380 and 381). In the petrol car transmission gear the most usual combination is the following: Generally the motor shaft works the main shaft, the two being in a direct line, by a clutch which enables the two to be connected or disconnected; generally the gear provides for the forward and backward motion of the car and as a rule it gives a series of speeds. Spur wheels, belts, or friction wheels transmit the main shaft motion to a cross countershaft; or instead a system of gearing including a universally jointed longitudinal shaft transmits the motion direct to a revolving rear axle. The cross countershaft carries the differential or balance gear. Finally, the differential shaft works the car wheels by endless chains passing over sprockets bolted to the wheel naves. These different parts will be studied in succession.



Figs. 357.—Serpollet Chain Drive.

With regard to transmission gear in steam automobiles, this is simplified greatly by the progressiveness of the action of steam, which renders the use of a clutch between motor and gearing unnecessary by the elasticity of the motor, and by the facility for backward movement, which is accomplished always by reversing the valve gear, easily operated by aid of link motion and eccentrics.

In the de Dion-Bouton omnibus, the motor shaft drives by one of the two trains of gear at full or slow speed, the differential shaft motion being communicated by gearing to the " live " rear axle.

In the Scotte omnibus, the crank shaft drives an intermediary shaft by aid of two pinions, this latter shaft being connected to the differential by an endless chain, which in turn drives the rear wheels of the vehicle by two smaller chains.

In the Weidkneckt omnibus, motion is transmitted by gearing to the differential and thence by endless chains to the wheels.

The steam omnibus of the Compagnie Générale des Automobiles was driven by a rotary motor whose shaft had a friction clutch; the differential countershaft was driven by gearing, and it in turn drove the rear wheels. The changes of speed were obtained in a very satisfactory manner by the motor alone. The system of transmission in steam cars being simple and efficient, belts or friction plates are but seldom adopted.

The White steam car transmission (new model) is simplicity itself. The motor is in front and this is directly connected to a live rear axle by means of a universally jointed longitudinal shaft and bevel gearing; the bevel wheels are enclosed in the differential case.

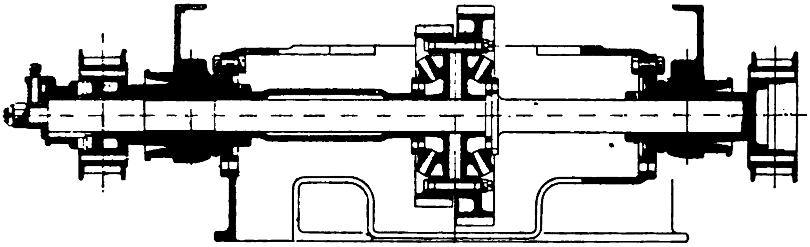


Fig. 358.—Coulthard Differential Shaft, Old Type.

In an earlier, but still modern, car the transmission is even simpler. On the casing of the live axle differential is a sprocket ring chain-driven from a sprocket on the motor crank shaft, which in this case is in the centre of the car. The Gardner-Serpollet system (Fig. 357) is almost identical with this.

The Coulthard old type transmission is shown in connection with the Coulthard motor (Figs. 76 and 77, p. 100). The motor crank shaft, carried in two long bearings, together with the eccentrics, is cut out of a solid steel billet, and on one end of the shaft is a pinion engaging with a gear wheel on the second motion shaft. On a square in the middle of this shaft slides a pair of unequal pinions, either of which may be caused to engage with corresponding gear wheels carried on the crown of the compensating gear. The compensating gear shaft is shown separately by Fig. 358, and it is the only shaft projecting through the casing. It carries a pinion at each end, and there is a locking gear for putting the compensating gear out of action and causing both of the driving wheels to revolve together. The whole of the gearing runs in a bath of oil, is of cast steel, machine cut, and keys are not used in the transmission gear. The compensating gear shaft (Fig. 358) is carried in long bushed bearings attached to the casing, and these bushes are in turn carried in spherical bearings supported in cast steel brackets rigidly bolted to the main channel frame. The method of supporting the motor cylinder end allows a ball-and-socket motion, so that the motor, motion work, gearing and shafts, being self-contained in a rigid casing, are kept in accurate mesh and alignment, whilst the method of suspension allows the main frame some elasticity and spring without setting up internal strains and cross wind in the transmission gear. Pivoted to the back axle under each side frame are two thrust rods through which the drive is transmitted to the compensating gear brackets. Renolds' improved chains are used, forming a flexible connection between the back axle and the compensating gear shaft.

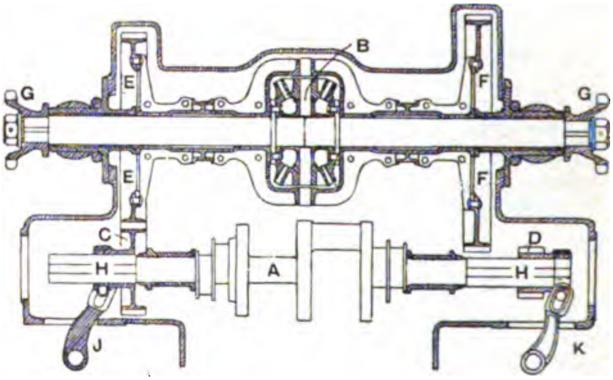


Fig. 359.—Coulthard Steam Lurry Transmission.

As an example of the simplicity of which the transmission and speed-changing gear of a heavy steam car is capable the Coulthard new gearing (Fig. 359) may be noted. The crank-shaft A, change-speed gear, and differential B are all enclosed in an oil-tight case. The crank-shaft carries two unequal pinions, C D, and C can be made to mesh with E for top speed, and D with F for low speed; E F are corresponding pinions fixed on the differential shaft which carries the side chain sprockets G. The crank-shaft A is squared at H, so that either C or D can be slid into engagement, J being the operating lever for top speed, and K for low speed.

In a system once employed by the Thornycroft Steam Wagon Company the motor transmits motion to the chain pinions by a belt which is supported on the motor shaft by a single pulley and on the pinion shaft by twin pulleys, each transmitting motion to one of the pinions. The belt is equally across the two pulleys when the car is running in a straight line, and when the car turns the belt is more on the outer pulley. The belt is kept in position by a fork worked by a screw moving in a nut, which is fixed in the direction of the displacement of the screw; the nut can turn on itself when the rod and lever which draw it are displaced in the turnings of the road. This transmission gear can work without any differential. The modern transmission is described on p. 518.

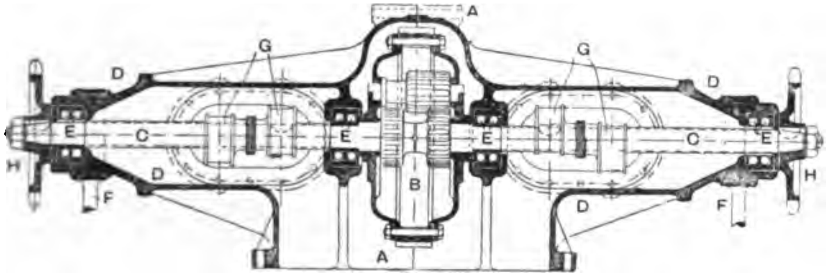


Fig. 360.—Chelmsford Steam Car Transmission.

The Chelmsford steam car transmission is also very simple, and no change-speed gear is employed. As stated on p. 84, the spur-wheel G, Fig. 59, directly drives a phosphor-bronze wheel surrounding the differential, from the shaft of which there is a chain drive to each road wheel. This phosphor-bronze wheel is shown at A, in Fig. 360. The spur-wheel type differential B, with its countershaft C, are enclosed in a two-part casing, D, divided vertically and centrally, and the gear wheel A is bolted between the two halves (Fig. 360 is a horizontal section). The shaft C has four double ball-bearings E, containing 12·7 mm. (·5 in.) balls. The casing D is bolted at each end to the main frame, and distance rods, F, fitted at its ends, pass down to the rear axle and tighten the side chains when necessary. The eccentric blocks G on the shaft operate four feed pumps, as described on p. 84. Sprocket wheels, H, at the ends of the countershaft are fitted as usual.

A friction drive applied to a steam lurry is described in connection with the Aultman lurry, p. 539.

The greatest complication in the transmission gear is found in petrol cars. Excluding friction drives, and other more or less fanciful systems, power transmission in a petrol car is either by belts or toothed gearing.

Belts may be considered first. For every different speed the main shaft has a large, permanently fixed pulley, and the intermediary shaft has two juxtaposed pulleys, one keyed and the other loose, a belt running to all these pulleys. To engage, the belt is made to pass, by means of a fork, by lateral displacement from the loose pulley to the fixed one. It is not usual to drive the transmission gear through a clutch. Sometimes the set of pulleys and belts is replaced by a single belt and two cones with parallel axes so placed that the large base of one is opposite the small base of the other. These cones have notched or smooth sides to enable progressive variations of speed, a belt stretcher being necessary to engage the gear. Instead of cones two extensible pulleys can be employed, and then the belt does not move transversely, but the diameter of the pulleys changes under it to keep it taut and give it variable speeds (*see* p. 422). Defective adherence is′ the great inconvenience of belts, because it causes a considerable loss of power. To increase the adherence, sometimes indiarubber belts are used on leather-covered pulleys. Other defects are the necessity of often restretching the belts and the great space occupied. The advantages are that they are simple, economical, silent, and sufficiently elastic to avert all risk of smashing any part by an abrupt change of speed, etc. By its means, also, the reversing gear may be used as a brake, an impossibility with gear liable to breakage. With belts, retrograde motion is obtained by a set of pulleys united by a crossed belt. In modern systems, belts are used chiefly in connection with toothed gearing (*see* p. 418).

Belt systems of transmission, formerly used extensively, are cheap and durable. In the Roger type, as built by the Anglo-French Company, there were two large pulleys of different diameters on the crank-shaft, and on the cross countershaft were two couples of pulleys, one fixed and the other loose, the combined diameter of which was equal to that of one of the pulleys on the crank-shaft; there were then two speeds. Another set of pulleys with a crossed belt gave backward motion. There were two pinions on the cross countershaft, which, by means of chains, drove the live rear axle carrying the differential, the driving wheels being keyed on the two parts. This system of transmission was employed by the Delahaye, Audebert-Lavirotte, and other firms.

When toothed gearing is employed, it is almost essential that the motor drives the shafting, etc., through some form of clutch capable of quick and easy engagement and disengagement. Clutch gears include the crab or jaw systems, friction (straight or inverted cones with bands), magnetic, and hydraulic, but the majority of clutches are of the friction type. In crab or jaw clutches there are two sleeves, one on the end of each of the shafts to be coupled together; the first sleeve is fixed and the second is movable longitudinally, and both have projections and slots for mutual engagement. For a reverse motion there may be two of these clutches, one on the end of each of two shafts driven by a single bevel pinion on the motor shaft. Each of the driven bevel wheels is one with a part of a jaw clutch, the counterpart being a sleeve sliding on the transmission shaft. Normally, the bevel wheels ride loosely and do not transmit motion, but when the clutch sleeve on either of the transmission shafts is advanced, engagement occurs, and there is either forward or backward motion, according to which shaft is driven.

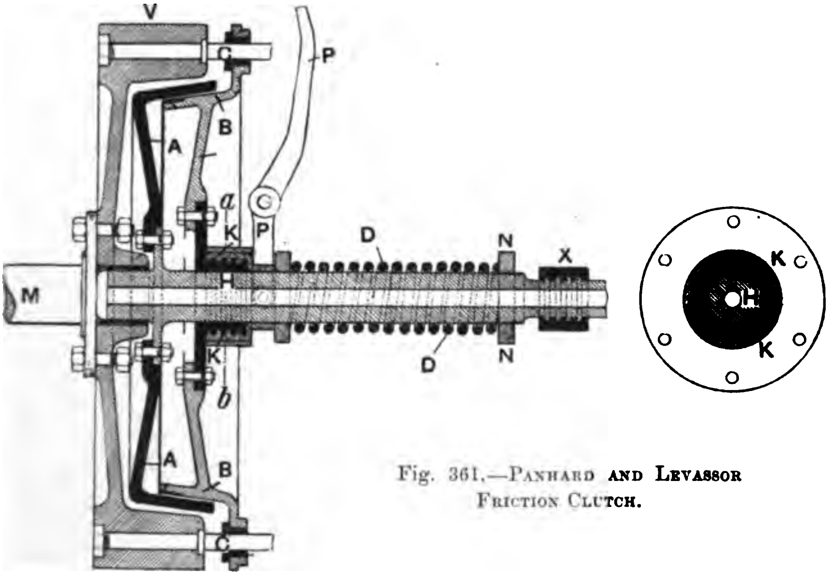


Fig. 361.—PANHARD AND LEVASSOR FRICTION CLUTCH.

To run the car forwards the sleeve keyed on the forward motion shaft is pushed towards the clutches of its socket, and the latter is connected with the former, which it entrains as it moves. For backward motion the other sleeve is geared. Clutch couplings do not allow of easy starting; the strains undergone by the car are transmitted to the motor, causing a risk of the motor parts being broken or jambed, with consequent disturbance of the valves. For this reason the main clutch is usually of a more flexible nature—the friction type—and jaw clutches are reserved for minor applications.

The friction clutch with straight cones has a cone keyed down on each of the shafts to be connected, one fixed and the other movable longitudinally to enter into the first, under the action of a fork moved by levers and a pedal. The most common arrangement is for the motor shaft to carry a hollow cone and the other shaft a solid cone maintaining a spring, the latter normally inside the former. The driver, by means of a pedal lever, can instantly stop the action of the spring and throw the second shaft out of gear.

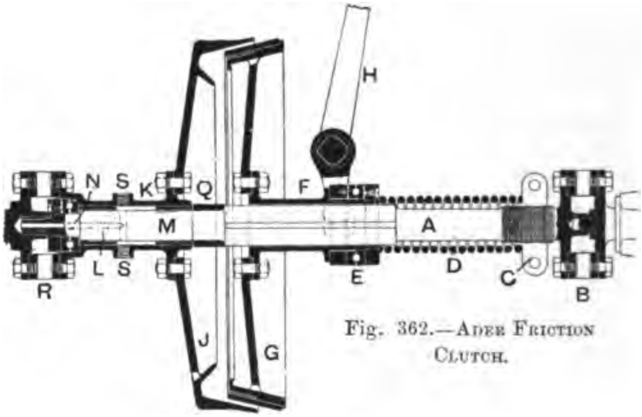


Fig. 362.—Ader Friction Clutch.

Inverted cones are so shaped that the solid cone can enter the hollow one only in two pieces, the hollow cone being constituted by a conical ring which is screwed to the solid cone of which it forms the outer surface. The clutch is operated by separating the end of the solid cone from that of the hollow one by traction, and not by bringing them close by pressure as with the straight cone coupling. Whichever of these two systems is employed, an inconvenient thrust is exerted on one of the bearings surrounding the coupling, and this thrust is avoided with the following systems.

The Panhard and Levassor new cone friction clutch is shown in longitudinal section and cross-section (on the line *a b*) by Fig. 361, p. 369. Two conical surfaces, A B, come into contact; the cone A, bolted to the flange on hollow shaft H, then is driven by the cone B, which is loose on the shaft H, but is fixed to shaft M. B is rotated by studs C C, set in the rim of the motor fly-wheel V. These studs project so as to form sliding guide rods for the backward and forward movement of the sliding cone B, when this is actuated by lever P operating through sliding collar K. The two cones are maintained in driving contact by the pressure of spring D, whose thrust-block is the collar N, fixed on shaft H. The dished fly-wheel V is bolted to the flange on the end of motor shaft M, and the hollow in its boss forms an end bearing for shaft H. The thrust of the spring at the moment of disengaging is taken by the thrust bearing X, but there is no thrust when the two cones are in contact. When the cone B is withdrawn from driving contact with cone A, it revolves freely on the shaft H and in the collar bearing K, but it does not rotate the shaft, although it continues to revolve with the fly-wheel V. Both of the cones are mounted upon the hollow shaft H, and the fly-wheel does not form part of the clutch; this prevents end thrust upon the crank-shaft.

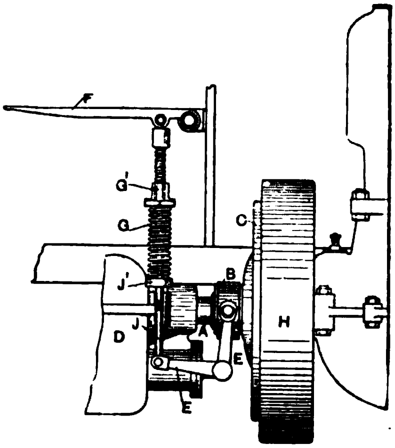


Fig. 363.—De Dietrich (Turcat-Méry) Friction Clutch.

The Ader friction clutch (Fig. 362) is designed so that the thrust is taken by ball bearings, not by the crank shaft or main driving shaft. The clutch shaft A has a flexible joint B, through which power is transmitted to the change-speed gear. The bolt C is a bearing for the clutch spring D, which acts through the sliding ball-bearing E, on sleeve F, which slides on the square part of shaft A. This sleeve carries the leather-covered aluminium male cone G of the clutch; the lever H puts the clutch out of action by separating G from the cast-iron female cone J, carried by sleeve K, which revolves round shaft A on rings L M. Q is another ring. The sleeve is driven by the motor through connection R, and when the clutch is out of gear, turns freely round shaft A, whose ball bearings are shown at N, and lubricating holes at S. On releasing lever H, the spring pressure, adjusted by screw C, acts through the sleeve K, and brings the two cones together.

Though the de Dietrich (Turcat-Méry) cone friction clutch is of the usual kind, its spring is placed in a novel position (*see* Fig. 363), in which G is the clutch spring adjusted by nut G^1. The lower end of the spring is set in a formed bracket, J^1, whilst its upper end bears against the special turret nut G^1. By altering the position of the nut on the pedal rod J, and so increasing or reducing the compression of the spring, the grip of male cone surface with the female can be varied at will from above the footboard. Another point is that the clutch C in fly-wheel H is near to the gear-box D, to avoid the twisting of the clutch shaft A. In Fig. 363, B shows the ball thrust bearing, E clutch lever crank, and F clutch pedal.

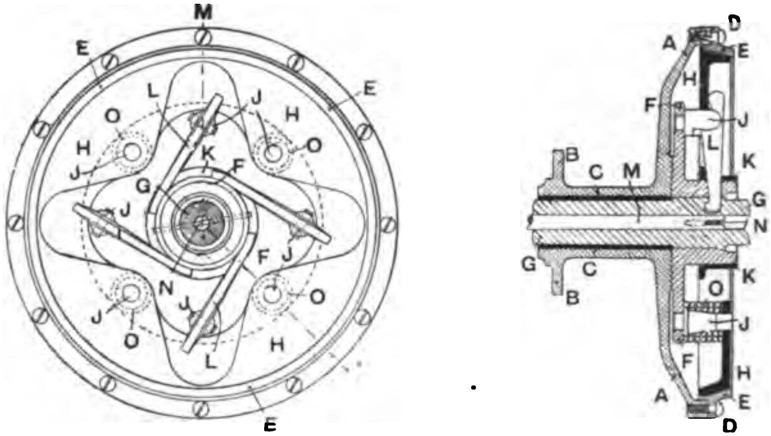
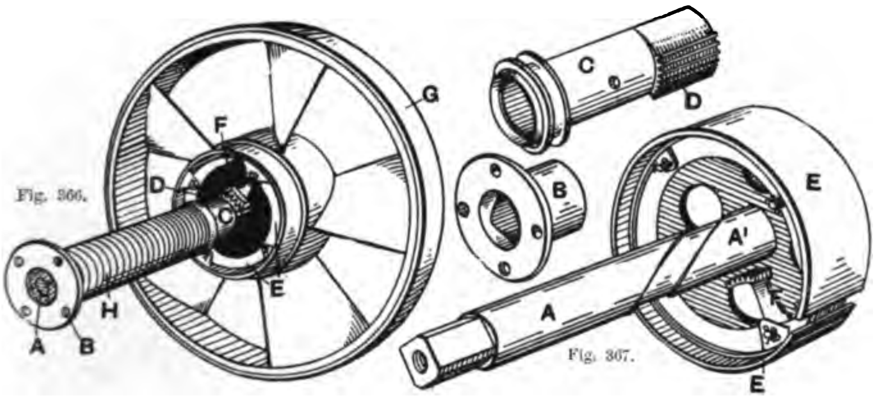


Fig. 364. Fig. 365.

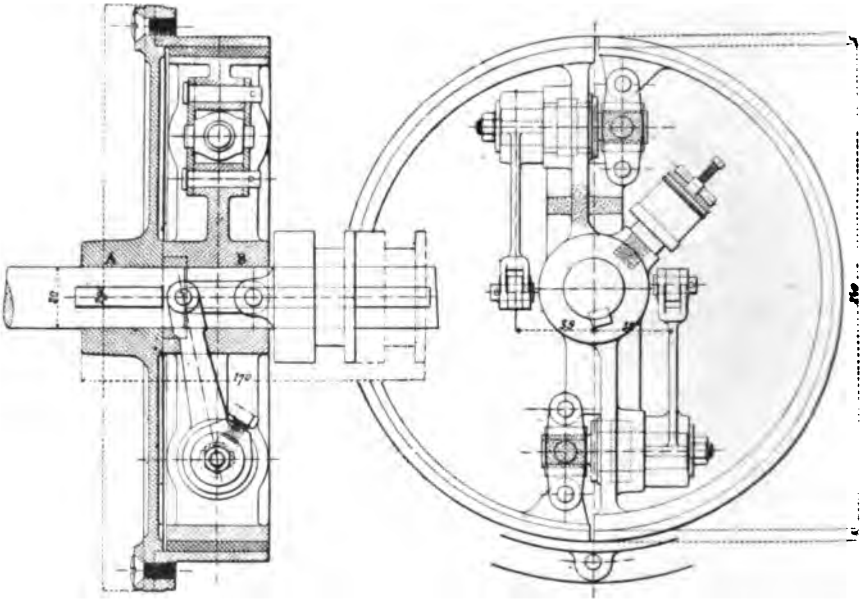
Figs. 364 and 365.—James and Brown Friction Clutch.

The James and Brown clutch is of novel construction. It is shown in elevation and section by Figs. 364 and 365, in which A is the clutch shell formed with a flange, B (bushed at C) to carry the driven steel pinion (H, Fig. 364). The shell is dished and flanged for the attachment with set screws, D, of the female cone E. The disc F has a hollow boss, and is keyed to the clutch shaft G, which extends between the outside bearings of the two gear boxes (T, Fig. 419, p. 414), and carries upon its square portion the gear wheels (K, J, L, M, Fig. 419). The drive from the clutch shell A is conveyed through the male cone H, driving pins J and disc F to the clutch shaft G; the disc F is called the driving plate, and upon its hollow boss is mounted the clutch collar K, through which pass the disengaging levers L. The clutch striking rod M is connected to the collar K by cotter N, and on moving it to the right the collar moves similarly, and causes the disengaging levers L to work on their fulcrums J. Thus the short noses of the levers L press against the male cone web H, the springs O are compressed, and the coned periphery of the male cone H is pressed back from contact with the internal coned portion of E. The male cone H is cast with a quatrefoil sinking in its outer face to accommodate the bosses of the driving plate F, the clutch collar K, and the levers L, with their fulcrums J. Only a very slight movement of the rod M is necessary to disengage the clutch.



Figs. 366 and 367.—Mercedes Expanding Clutch.

The Mercedes expanding clutch in use on the 1903 cars is shown by Fig. 366, the inner portions and some details being shown separately by Fig. 367. It is contained inside the combined fan and fly-wheel, of which the boss forms its outer member. E is the expanding portion. The fly-wheel is fixed to the crank shaft, and has its spokes shaped as fan blades, the bulk of its weight being provided in the rim G. The inner member of the clutch is mounted on shaft A, which is connected at its outer end to the first-motion shaft by the flange B. Shaft A has spiral projections, A^1, upon it, and these fit corresponding spiral grooves inside the sleeve C, which fits over it. Normally sleeve C is held in a forward position by the helical spring H, and can be withdrawn by a fork engaging in the groove shown on its end. It has teeth, D, forming a sector at the front end, and these engage in a similar quadrant, F, carried by a bell-crank lever as shown. When sleeve C is moved longitudinally on shaft A, the spiral path between them causes it to rotate about the shaft, and the teeth D then make the bell-crank lever rock about its pivot. The bell-crank lever expands the ring E, or allows it to contract.



Figs. 368 and 369.—Section and End View of Piat Friction Clutch.

An expanding clutch employed on the Mercedes 18-h. p. car, shown at the Agricultural Hall Exhibition, of March, 1903, differs considerably from the above. The expanding portion is operated by a sliding cone, which is moved along the shaft by a spring, and against which presses the lever arm expanding the inner portion of the clutch. The cone has an almost spherical surface, and, of course, is withdrawn by a pedal. An intermediate short shaft with flange couplings is inserted between the clutch and the first motion shaft.

The Charron, Girardot, and Voigt clutch resembles a band brake; the fly-wheel carries the band which tightens on a drum connected by a universal joint with the first-motion shaft. A pedal is connected with a sliding cone on the gear shaft, which, by means of a lever, tightens the band.

The Piat friction clutch, Figs. 368 and 369, consists of two parts—the cup A and friction pulley B, which can be combined in two ways. To couple them they are keyed on two shafts respectively, prolonging each other, or one is loose and the other fixed on a common shaft to enable engagement and disengagement without loss of speed by gliding. There are two breaks diametrically opposite in the rim of the friction pulley; each half forms a flexible arm, decreasing in thickness from one extremity rigidly connected with the nave to the other, which is pushed open by a screw mechanism or allowed to shut. Around this pulley is a leather packing to augment the coefficient of friction and to render oiling unnecessary. The threads of the two screws are at an angle of 45°, and the screws serve to extend the pulley's flexible arms, and they are governed by hinged cranks by aid of small connecting rods on each side of the coupling sleeve, which rotates with one of the shafts and can be displaced under the action of a forked lever. The axle of each of the cranks is prolonged by one of these screws and rotates in the radial arm of its flexible half-arm. This screw acts on a nut pivoted loosely in a strap hinged at one end with the thin part of the other flexible half-arm. Thus coupling can be operated gradually and smoothly and disengagement

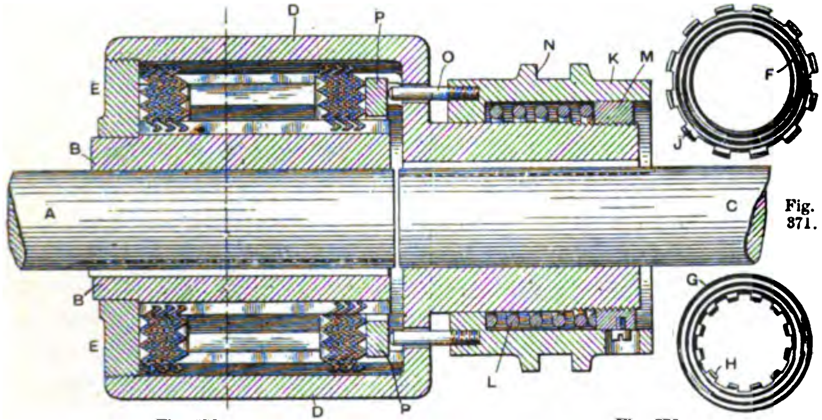


Fig. 370.

Fig. 371.

Fig. 372.

Fig. 370.—Hele-Shaw Friction Clutch. Figs. 371 and 372.—Friction Discs.

can be made instantaneously. The apparatus is balanced perfectly, and as entraining is caused only by vertical pressures to the exclusion of all lateral pressures there is no translatory resultant in the couple of rotation. All parts of the clutch are made of cast steel, reducing the weight, giving great elasticity and resistance, and increasing the co-efficient of friction.

Prof. H. S. Hele-Shaw has invented a friction clutch of the Weston type in which engagement occurs between the faces of two series of parallel discs feathered alternately to the driving and the driven shaft. Considerable axle pressure is required to effect the engagement in such clutches owing to the flat form of the discs, but Prof. Hele-Shaw replaces the flat surfaces with conical ones. Fig. 370 is a longitudinal section of the clutch. On the end of the motor shaft A is keyed a sleeve, B, on whose outer surface a number of feather ways are formed. On the end of the shaft C is keyed a sleeve, D, which extends over the sleeve B, and in its bore a number of feather ways are similarly formed. The annular space between the sleeves B and D is closed by cap E, screwed into the end of the driven sleeve D, and in the space is packed a large number of sheet metal discs, F G (*see* Figs. 371 and 372), a few only of which are shown in Fig. 370 for the sake of clearness. These discs are each deeply corrugated, and when their conical surfaces are pressed into close contact, the apices of the corrugations do not bottom in the grooves ; the clearance obtained gives the full advantage of the jamming or wedge action of the cones, and preserves the apices where the material is most likely to suffer in the stamping process from wear. The discs are grouped into two sets: the set G is made with internal projections or tongues, H, to engage with the feather ways of the sleeve B, their peripheries being clear of the casing D ; set F is similarly feathered by the external tongues J to the casing D and clears the sleeve B. The corrugations in the discs are circumferential and concentric, and extend over the projections H or J. In order to give the pressure to cause engagement, on sleeve D is mounted a sliding spring box, K, with an internal spring L. This box is urged to the left by the spring which abuts against the collar M, and it is controlled in the usual way by a forked lever engaging in the groove N. The thrust of the box K is transmitted by a number of pins, O, to the annular plate P bearing against the first disc of the series. When the spring box is left uncontrolled, the shafts are engaged by frictional contact of the discs due to the pressure of the spring L, transmitted through the box K, the pins O and the end plate P, and there is then no external reaction and very little friction between the controlling fork and the groove N. To disengage, the spring box is forced to the right by the controlling lever, relieving the engaging friction. There is then pressure between the controlling fork and the groove, and external reaction, but as the driven shaft is then at rest there is no friction. Prof. Hele-Shaw says that the gripping power of the clutch is very great, and that the action is quite efficient even when the friction surfaces are well lubricated.

Several other kinds of friction couplings are employed for cars. In the Megy system the circular band is applied by aid of spiral springs arranged in a string against the friction cup; normally these springs do not press against the band, but exert a thrust on it when a pin is placed between them. The apparatus is reversible, and with a special device can be employed for speed-changing. In the Herschmann hydraulic clutch the adherence of the spring and the friction cup is produced by oil admitted by a valve. Hall's hydraulic clutch gives a variable speed, and it has been tried practically; however, it is very complicated.

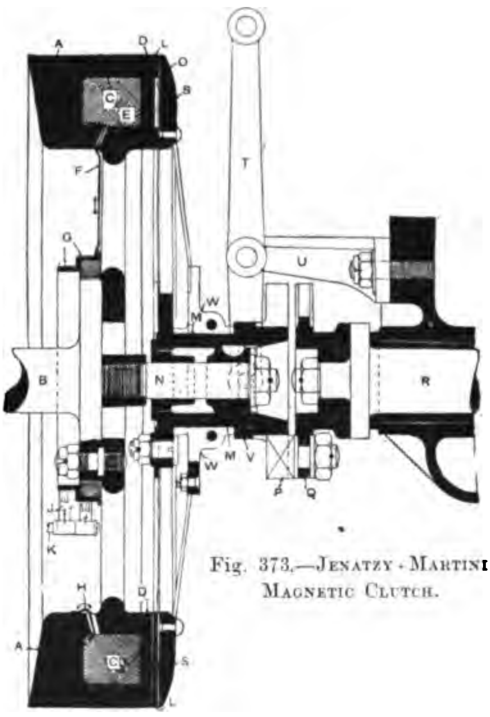


Fig. 373.—Jenatzy-Martini Magnetic Clutch.

Krebs once had an idea for a magnetic clutch on the principle found in the magnetic clutch of de Bovet, in which adherence is obtained by electro-magnetic action.

The Jenatzy-Martini magnetic clutch has the flywheel as a part of it. Fig. 373, a cross section, shows the steel flywheel A to be bolted to a flange on the end of the crank-shaft B. The rim is grooved out at C to contain a coil of insulated wire, which is wound in the shape of a large ring, and fits in the groove. A steel ring, D, is fixed as shown after the wire winding is in place, the ring having slots cut through it at intervals, which are filled with blocks of anti-friction metal, E. The one end of the coil C is connected by a wire, F, to contact rings, G, which are insulated from the flywheel, and revolve with it. The other end of the coil C is earthed at H. The electric current which energises the clutch by magnetising its flywheel member, is led to the coil through two brushes, J, which are both in electric connection with a battery or dynamo through the pin K, on which they are fulcrumed; this pin is mounted on the crank chamber of the motor, and is, of course, insulated from it. Two brushes are fitted so as to ensure a good contact with the slip rings, even should one brush jump. An iron disc L, 3 mm. (·12 in.) thick is fixed to a sleeve M, which revolves upon a bearing providing by the pin N, projecting from the flywheel. This sleeve is free to move a certain distance longitudinally, and therefore the disc L can be brought into contact with the flywheel ring D, or can be moved away from it. Slots O are formed at intervals in the disc L, as indicated in Fig. 373. The sleeve M terminates in a flexible coupling member, P, and by means of this and the other member, Q, it is connected with the driving shaft R of the gear box. A steel ring, S, lies outside and alongside the ring L, and is carried by a split sleeve W, which revolves freely outside the sleeve M. This ring S forms the armature of the clutch, and is caused to grip the disc L between it and the pole piece ring D, when they are magnetised by the passage of the current through the coil C. The ring S is mounted freely, and is not rigid either with the driving or the driven portions of the clutch. Although the clutch members are drawn together magnetically, and the force exerted can be varied, yet the same pedal which controls the clutch electrically is also connected mechanically with the sliding sleeve M, so that the disc L and the ring S are moved out of contact with the flywheel ring D when the pedal is fully depressed. This mechanical connection is very similar to that employed for operating an ordinary friction clutch, the pedal being connected with the lever T, which is pivoted to the bracket U, and engages at its lower end, through the ring V, with a groove in the sleeve M. (The letter reference, W, is given above). As the clutch pedal is depressed, the degree of magnetism holding the clutch members together is gradually reduced, and finally the sleeve M is moved rearwardly to separate the clutch members. The current on its way to the brushes J, and thence through the clutch coil C to earth, is led through a variable resistance device mounted in front of the dash beneath the bonnet. This apparatus consists of a rotary six-pronged switch drum, the stationary contact pieces for which are connected with fine wire resistances contained in the base of the apparatus. When the pedal is pressed down, the switch drum rotates about its axis, gradually cutting in more and more resistance into the circuit by drawing the contact arms away from their stationary contacts. There are six arms and six contacts, so that the amount of current passing through the clutch coil is reduced in six stages. The lines of force in the magnetic circuit pass through the armature ring S; and the force exerted in holding the disc L and the armature S solid with the flywheel is enormous, although the maximum current required is only half an ampère, at an E.M.F. of 16 volts. The number and sizes of the slots O in the disc L are important, and have been so proportioned that, whilst on the one hand, a sufficiently powerful grip is assured, yet, on the other hand, the disc L is easily released when the clutch pedal is fully depressed. The great advantages of this magnetic clutch are: (1) that any desired degree of slip can be permitted; (2) that the car can be started gradually and without shock; (3) that very little pressure need be exerted on the operating pedal, and (4) that the momentum of the revolving parts connected direct with the gear shaft R is unusually small, owing to the fact that the only clutch member rigid with it is the disc L, this rendering the manipulation of the change-speed gear exceptionally easy, and tending to increase the life of the change-speed gear considerably.

Typical clutches having been discussed, the general arrangement of toothed transmission gears may be studied. Generally, as many pinions as rates of speed to be obtained are keyed, screwed, or brazed on the main shaft (first-motion shaft). An equal number of wheels is on the driven shaft (second-motion), and they remain free to glide longitudinally, so that successively each can be made to engage with its corresponding pinion; most frequently the wheels are carried by a sleeve which runs along the shaft; or sometimes, the shaft itself moves lengthwise. Sometimes the main shaft pinions glide along, and the toothed wheels then are keyed on the second-motion shaft, and instead of being juxtaposed may be concentric, in which case the shaft on which the pinions are mounted occupies the position of the horizontal diameter of the common circumference. The respective radii of these toothed wheels are calculated so as to reduce the number of revolutions of the main shaft in proportions suitable for the required speeds of the car. The greatest reduction found in practice is that of 18 to 1, employed in the Kriéger electric fore-carriage. Backward or reverse motion, operated usually at slow speed, is obtained by interposing a pinion between the sets of toothed wheels, so that the second-motion shaft (now the third-motion) revolves in the same direction as the driver shaft.

When toothed gear is well cut the loss of power is small, and

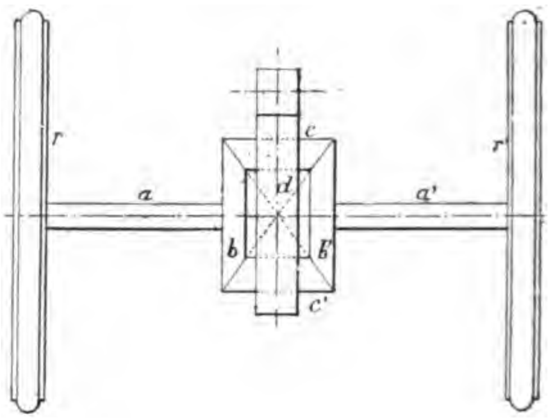


Fig. 374.—DIFFERENTIAL GEAR WITH CONICAL PINIONS.

there is the further advantage of but little space being occupied; but it is costly without being elastic, and it is noisy if raw hide gear or bevel gear is not employed. It does not allow of the vehicle passing progressively from one speed to another. To change speed one must disengage and alter the wheels in gear, and if this is not done skilfully it is easy to damage the teeth.

If the two driving wheels of a car are keyed upon their axle in such a manner that they are obliged to constantly perform the same number of revolutions at the same rate of speed on a straight road, they will revolve in harmony, but when making the least turn the inside wheel, having less distance to travel, will skid, causing friction and wearing away the tyre, and the security of the vehicle will be endangered. By means of the differential gear the wheels revolve independently of each other. Instead of being in one piece, the axle is in halves, a a^1 (Fig. 374); one of the wheels, r r^1, is fixed on each half, and also a pinion, b b^1, gearing with pinions c c^1; these pinions move around their axles, which run along two radii of the toothed wheel d, with which they form one. This wheel is driven by the motor shaft by aid of the pinion visible above. With this device the wheels proportion their speeds respectively to the roads on which they run. Instead of being formed of cone gearing the differential may have plane pinions, which are less cumbersome (*see* Fig. 375). Conical or flat, they are generally enclosed in a gear case, which will hold oil and protect them from dust.

The road wheels have been supposed to be keyed on their axles,

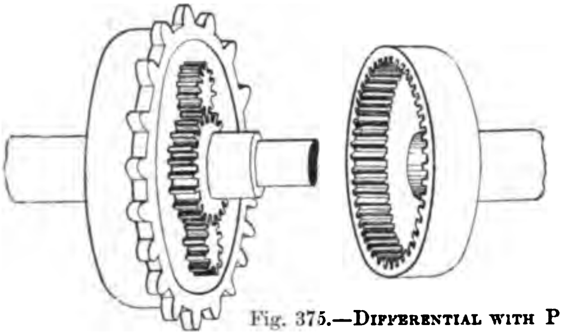


Fig. 375.—DIFFERENTIAL WITH PLANE PINIONS.

but they are generally loose, driven by endless chains gearing with sprockets keyed on the intermediary shaft. A differential gear on this shaft now is necessary, or it can be replaced by a pawl and ratchet gear. Brouhot formerly had a toothed wheel on the nave of each wheel (*see* Figs. 702 to 704, p. 653), and on each end of the axle a plate around whose axis was hinged a three-branched click, the lower one being engaged in a cavity of the axle. When the axle turned, the click rocked around its axis, and one or the other of its higher branches, according to the direction of the motion, engaged in one of the notches of the cog-wheel, and entrained the wheel of the vehicle. When the vehicle was turning, the outer wheel, to acquire a greater speed than the other, had only to run before the click, the click returning into contact with the toothed wheel when speeds were again the same.

It is a question whether or not it is desirable to dispense with the sensitive differential, which often acts when not required, as, for instance, when one only of the wheels meets with an obstacle. Then one wheel stops or does not run so quickly as the second and tugs the chain in a destructive manner, leaving the other chain to work alone. However, the majority of constructors consider the differential to be necessary, and there are but very few modern cars on which it is not fitted on either countershaft or rear axle.

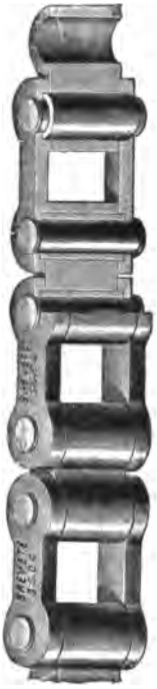


Fig. 376.—Benoit Block Chain.

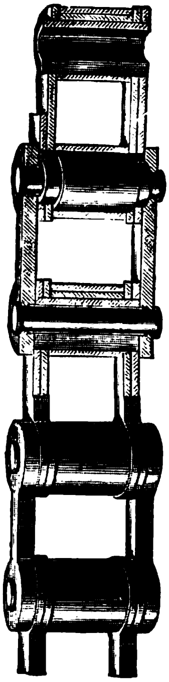


Fig. 377.—Benoit Roller Chain.

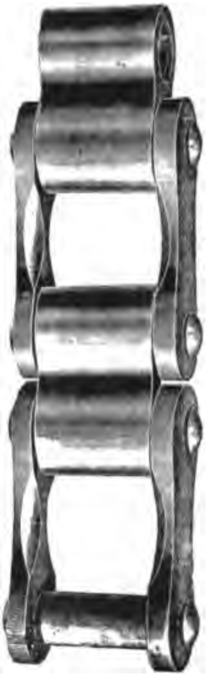


Fig. 378.—Brampton Block Chain.

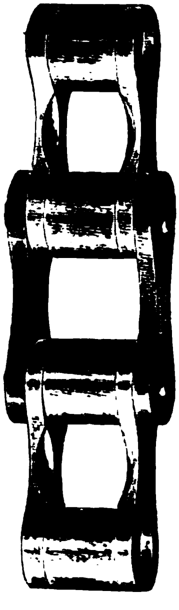


Fig. 379.—Brampton Roller Chain.

When the rear axle is not a driving or "live" axle with road wheels loose upon it, the cross countershaft, as a rule, carries two sprockets, which, by means of endless chains, drive two toothed wheels on the spokes or hub of the driving wheels. Motor chains resemble bicycle chains with blocks or rollers. Block chains consist of elongated links, in which gear the teeth of the wheels, the links being connected to each other by shorter solid links fastened with chilled steel rivets. In roller chains all the links are elongated, and they are united by rivets, which form pivots, around which the rollers can turn freely. Any gliding of the solid links of the block chain on the toothed wheels is replaced in the roller chain by the running of the rollers, and, theoretically, the efficiency should be greater in the roller chain. Benoit's block chain, Fig. 376, is constructed with a view to making friction and wear bear upon the interior surface of the solid links, and the exterior surface of the sockets surrounding the axles. Chains suffer greatly from wear; by elongating their pitch the teeth are prevented from fitting exactly, and the looseness causes losses in power transmission. Benoit endeavoured to replace the blocks with double rollers, the dimensions being calculated so as not to require any alteration in the toothed wheels, and the improved chain gives great smoothness, and though of somewhat delicate construction is less liable to smash than a block chain. In a third type of chain (Fig. 377) constructed by the Benoit firm the same interval is made between all the rollers, and only one roller works in each tooth. This chain has the advantages of the second type, whilst being lighter and cheaper. Evidently it is desirable to standardise chains by forming guiding rules, which, however, must not hamper the constructor. The Touring Club of France organised a commission, which proposed the following dimensions:—

Block and Double Roller Chains.			Single Roller Chains.		
Pitch.	Width.	Solid.	Pitch.	Width.	Solid.
mm.	mm.	mm.	mm.	mm.	mm.
35	20	24	25	13	11
40	20	28	30	15	13
45	20	32	35	20	16
50	20	36	40	20	18
60	25	42	50	25	22
70	30	48	60	30	27
85	35	60	75	35	33
100	40	70			

By the word "solid" in the above table is meant the length of the solid parts, by "width" the inner breadth of the space, and by "pitch" the length of the solid and the space.

The Brampton block chain is shown by Fig. 378, the roller chain by Fig. 379, and the duplex roller chain by Fig. 380.

The Brampton special lubricated heavy chain is designed with the object of ensuring that the inner surface of each roller is lubricated efficiently. For this purpose each rivet is drilled with a hole, A, Fig. 381, in its centre, and into this a passage, B C, leads from outside the rivet (*see* Figs. 381 and 382). Hole A is countersunk, and a light spring, D, and a 6·3 mm. (·25 in.) steel ball, E, are inserted, and then held in place by spinning over the edge of the counter sinking, as at F.

The Renolds chain, known also as the Varietur (Figs. 383 and 384) was designed to avoid the inconveniences due to elongation of the pitch; the links are united by pivots, and their top part is slightly curved and the lower part constituted by two triangular teeth joined by a semicircle. The gearing has suitably cut teeth, and the two sets of links being hinged on the same pivot, they sink like wedges between the teeth, which they hold strongly. If the pitch happens to alter by elongation the triangular wedges sink less between the teeth, but the gearing remains just as close. It is claimed that the form of the top part, somewhat similar to that of a belt, more or less prevents dust from getting into the teeth of the wheels. The chain runs silently.

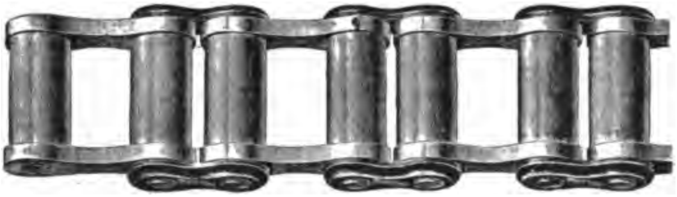
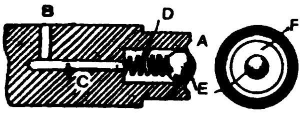


Fig. 380.—Brampton Duplex Roller Chain.

Motor chain links so often rupture that it is usual to carry a spare chain in the car; and some constructors, especially Jacquet and Bordet, have endeavoured to make chains with links which, when broken, can be replaced easily during a journey.

Whatever be the system employed, there must be a pliant connection between the differential shaft and the axle, the distance between which varies with flexion of the springs; but in order that it may vary as little as possible, the two parts are united by a distance rod, hinged at each end, which makes the axle describe part of a circle around the shaft. The horizontal component of this motion is obtained by placing the shaft and axle in about the same horizontal plane or inclining the nipper springs so that the relative displacement may take place according to a tangent to the course of flexion of the tops of the springs. To allow it to do so, flexible springs with rounded ends are employed, and they are united with the frame by side pieces which give them a certain amount of play. If nipper springs are employed, the pieces connecting the springs with the frame are made to slide in gussets.

The breakage of a chain, with the consequence that the car is left with one driving wheel only, may cause overturning if the car is moving at full speed; in any case it prevents continuing the journey, because the moving wheel describes a circle round the stationary one.



Figs. 381 and 382.

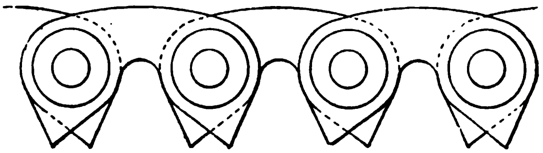


Fig. 383.

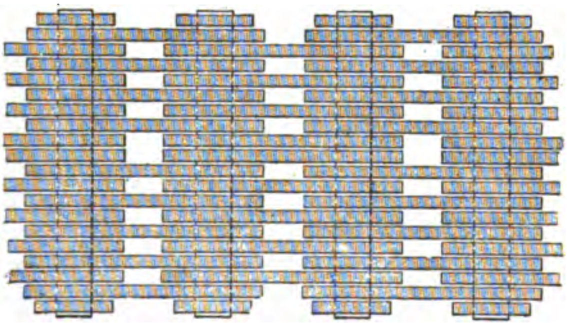


Fig. 384.

Figs. 381 and 382.—Brampton Lubricated Roller Chain.

Figs. 383 and 384.—Elevation and Plan of Renolds Chain.

If by arresting the differential gear it were possible to give the wheels interdependence, it would be possible to proceed with a single chain; this is the case with the Orient Express car, in which a ring glides on a socket, and by entering a clutch bars the differential.

The chief advantage of chain driving is the flexibility it gives to the transmission; and this flexibility is of particular value with a petrol motor whose couple varies every moment. With the electric motor giving a constant couple the chain can be dispensed with easily, and enclosed toothed gearing used instead.

Chains, in spite of their defects, but owing to their simplicity, are the most common medium of power transmission on automobiles, but, as has been the case with the bicycle, endeavours have been made to replace it by a device more easy to regulate and less liable to snap. The most popular chainless system is referred to in the next paragraph.

A large number of petrol cars have what is known as the "Panhard type" transmission gears. This originated with an early Panhard and Levassor car, and in its many modified forms is the most widely used gear at the present time. By means of it the motor ultimately drives a differential shaft whose ends are connected by chains to sprockets on the naves of the road wheels. Perhaps the majority of petrol cars employ this system, and the greater number of those which do not, especially among 1903 cars, have a chainless system, whose central and longitudinal shaft, universally jointed, drives a bevel gear on the case of the differential gear, which is carried by a "live" rear axle upon which the road wheels are keyed. The last two years have seen the abolition of many fantastic and elaborate transmission devices, and the majority of the better known cars have gears of the two kinds just mentioned.

The "Panhard type" gear will now be described in detail. The motor shaft carries a friction clutch shell, and in line with the motor shaft is the main shaft carrying the corresponding part of the clutch. By depressing a pedal, the two parts are put out of engagement; by partly depressing the pedal, there is partial engagement, allowing of a certain amount of slip, and thus, by carefully working the pedal, the motor and gear can be saved all sudden shock; when the pedal is up, there is complete engagement, although the clutch spring should be of just such a strength and so adjusted that it slips somewhat if the two parts of the clutch are brought together too quickly. At top speed, a motor making 750 revolutions per minute would revolve four times as fast as the road wheels, but for hill climbing the gear has to allow of the motor revolving, say, sixteen times as fast as the road wheels. The Panhard gear provides for this change of ratio by means of pairs of toothed gears or cog-wheels. A three-speed gear is shown in plan by Fig. 385, and in elevation by Fig. 386; a four-speed gear is the same, but for the addition of another pair of cogs. J is the main shaft in line with the motor shaft, and L is the top shaft driven off the former. The three unequal gear wheels, A, B, C, are on the main or lower shaft, above them being corresponding wheels A^1, B^1, C^1 on the top shaft. It is necessary to study the diagrams to get an idea of the relative sizes of these wheels. The driver's change-speed lever works the arms N^1, N^2, and N^3, and these have a fork which engages with a double flange on the sleeve M on the lower shaft. This sleeve carries the gear-wheels C, B, and A, and as the shaft is square for a portion of its length they can be moved to and fro upon it, and any one of them brought into engagement with its corresponding wheel on the upper shaft L. At the end of L is the bevel gear F, engaging with a bevel F^1 on the differential case G, and thereby driving the counter shaft H H. By means of sprockets on the ends of the counter shaft, chains drive the rear road wheels. A drum or pulley, R, on the counter shaft is encircled by the band of the pedal brake. The lowest gear is in use when A meshes with A^1 as shown. By pushing the change-speed lever a notch forward, C meshes with C^1 and gives the second speed, and when the lever is in the next notch, C passes through the teeth of C^1, and B meshes with B^1 and gives the top speed, the two shafts

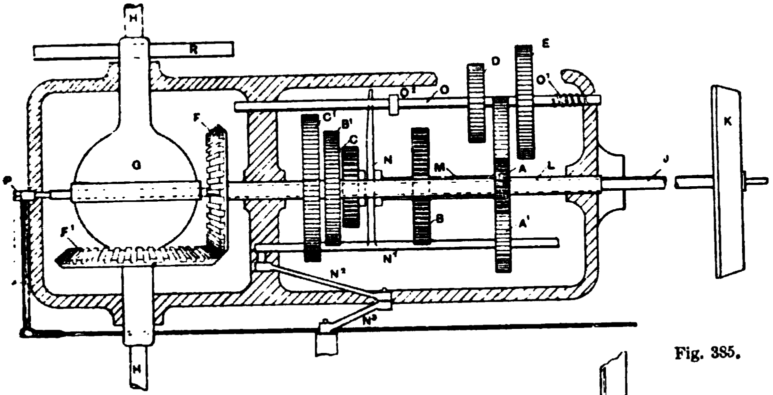


Fig. 385.

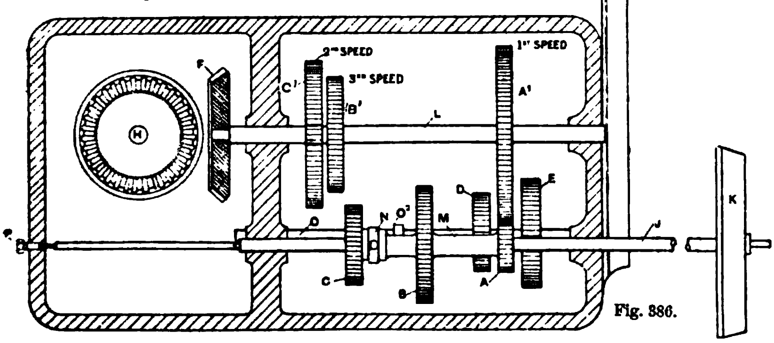
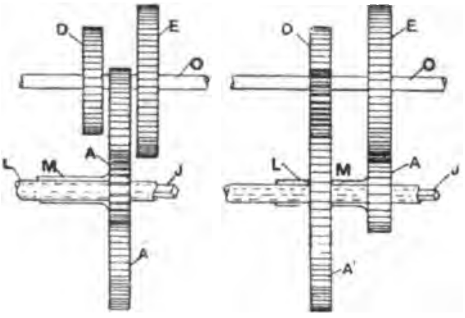


Fig. 386.

Figs. 385 and 386.—Panhard Change-speed Gear.

turning at nearly the same speed. (A feature of modern gears, chiefly those employing the universally jointed shaft and line axle previously referred to, is that there is a direct drive on the top speed; that is, the main shaft directly drives the rear axle at top speed, the auxiliary shaft transmitting power at the lower speeds only, although in most cases it always revolves whether it transmits power or not. Examples of such gears are described later.)

Reverse motion is obtained with the Panhard type gear by the use of the additional gear-wheels D E, Figs. 385 and 386. These are shown separately in Figs. 387 and 388, which respectively show disengagement and engagement. The wheels D E are fixed to a third shaft O, at one end of which is the spring O^1, and at the centre the stop O^2. On drawing back the change-speed lever, arm N comes against stop O^2, and at the same time the sleeve M and the gear-wheel A are slid along the square shaft J until A meshes with E. As the lever is brought further back, the sleeve M and the shaft O move in unison until the gears A^1 and D mesh together, as shown in Fig. 388. Now, the lower shaft J has no longer a direct connection with the top shaft L; instead, the connection is through the wheels D E on shaft O, so that the two shafts J L now revolve in the same direction as each other and not in opposite directions as before. As soon as the fork is disengaged by the change-speed lever, it ceases to press upon the stop block O^2, so that spring O^1 pushes back its axle and gear-wheels D E reassume their original position. The clutch K is regulated at P by means of a spring-controlled rod running right through the hollow lower shaft.



Figs. 387 and 388.—Panhard Reverse Gear.

In chainless transmissions the Panhard type gear still can be employed, but the top shaft is lengthened and the bevel at its end drives a bevel on the differential case of the back axle of the road wheels. Gears of this type, though perhaps modified, are employed on Ariel, Argyll, Hautier, Humber and other cars.

The Mercedes transmission retains the side chains, and a view of the 1903 change-speed gear is given by Fig. 389. A first-motion shaft is fixed to the clutch shaft by a flange-coupling, G, and the second-motion shaft, in the same plane with it, drives by bevel gearing, H^5 K^4, the differential K^5. The countershaft K^2, carrying the side chain sprockets, has a coupling, K^3, and is carried in outside bearings riveted to the frame. On the first-motion shaft are wheels, G^1, G^2, G^3 and G^4, which to obtain the first, second, third and fourth speeds are slid into mesh with the fixed wheels H^1, H^2, H^3 and H^4 respectively, on the second-motion shaft. These movements are effected by a disc-cam, J, revolved by a spur-wheel, J^1, forming one with it, the spur-wheel meshing with a toothed segment operated by the change-speed lever. Two levers, engaging with each of the sleeves carrying either pair of spur-wheels on the first-motion shaft, engage in the cam convolutions, which are so shaped that a continuous forward movement of the lever, and the consequent rotation of the cam, cause the spur-wheels to slide into mesh. For reverse motion an extra spur-wheel is brought into mesh between the low-speed spur-wheels by an extreme rearward movement of the change-speed lever. Also this intermediate wheel is controlled by the cam J.

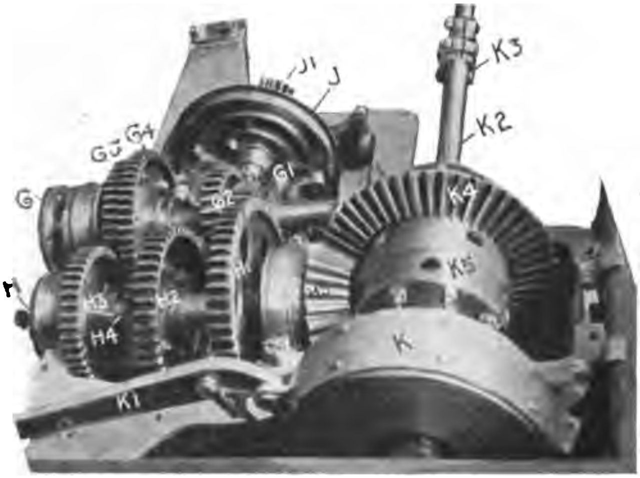


Fig. 389.—MERCEDES CHANGE-SPEED GEAR.

The Mercedes change-speed gear employed on the Milnes voiturette is shown by Fig. 390. A is the coupling for the clutch shaft, and the manner in which the toothed wheels on the first-motion shaft give the different speeds by gearing with those on the second-motion shaft B is at once apparent. The change is operated by the lever C. On the forward end of the second-motion shaft B is a brake drum D, and on the rear end is a small bevel which transmits motion to the large bevel E, surrounding the differential gear. The two parts of the countershaft F are carried in bearings rigid with the gear box, but these shafts do not themselves project through the outside brackets and carry the driving sprocket wheels. These sprockets are carried on separate small pieces of shafting connected with the actual countershaft by flexible jaw couplings, which allow of the removal of the gearing without disturbing the sprockets: further, any relative motion between the gear box and main frame is prevented by the flexible couplings from causing any strain on the countershaft.

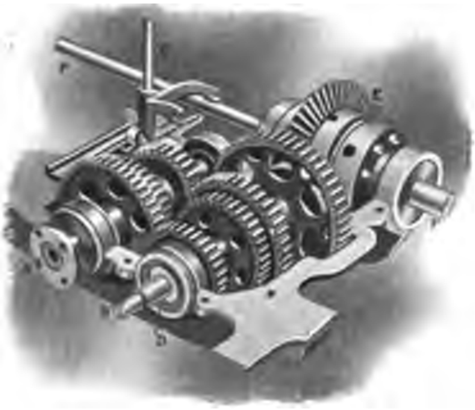


Fig. 390.

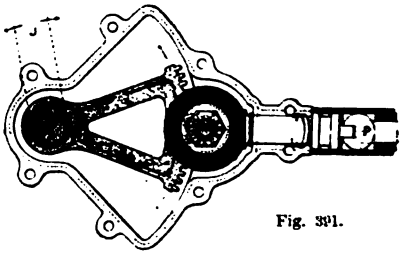


Fig. 391.

Fig. 390.—Mercedes-Milnes Change-speed Gear. Fig. 391.—Renault Operating Mechanism.

The Renault transmission is operated by the mechanism shown in sectional elevation by Fig. 391. The actual gear is illustrated by Fig. 392, in which the gear box and the mechanism that actuates it are shown in plan, and the clutch pedal *t* and the bevel drive to the live rear axle in elevation. The spur-wheels B, G and C, arranged for engagement with A, E and D, are mounted eccentrically in such a manner that they can be put in and out of mesh by the action of two toothed racks (one is shown to the right of the gear box) which cause the spur wheel *i* to rotate the second-motion shaft. The change-speed automatically draws B, G and C out of mesh before the sliding wheels A E are moved longitudinally on the squared main shaft, and then brings them back again into engagement with the required wheel. For the reverse motion, the eccentric intermediate spur-wheel S is brought down into gear with A and B, as soon as A has slid along the shaft past B. The hand lever J, shown in plan by Fig. 391, gives all the speeds, both forward and reverse, and is connected rigidly with the toothed quadrant L through shaft K; the quadrant rotates pinion M when the hand lever is moved. The pinion M is one with a bevel wheel, N, and so shaft P is rotated by means of bevel pinion O. Shaft P has cams which operate the racks already mentioned, and it has a quick-feed thread which gives a longitudinal motion to sleeve F. A fork connects F with the sliding wheels A E. As shaft P rotates, it moves the spur wheels B, G and C and the reverse-motion wheel S, in and out of mesh, and it slides along the sleeve that carries A and E. These actions take place relatively to one another; and when at top speed the wheels are in the position illustrated in Fig. 392, there then being a direct drive from fly-wheel V through the friction clutch U, the jaw clutch (shown between E and D), universal joints *r*, bevel pinion *s*, to the toothed bevel *t*, on the differential of the live axle; wheels B, G, C and S are now stationary. For the second-speed, wheel E is made to mesh with G, and to break its own jaw-clutch connection with D, at the same time C engages with D; thus the drive is through E, G, C, D. At the lowest speed the drive is through A, B, C, D. For reverse motion A engages with S, this with B, and the drive as before is taken through C, D, only in the reverse direction of rotation.

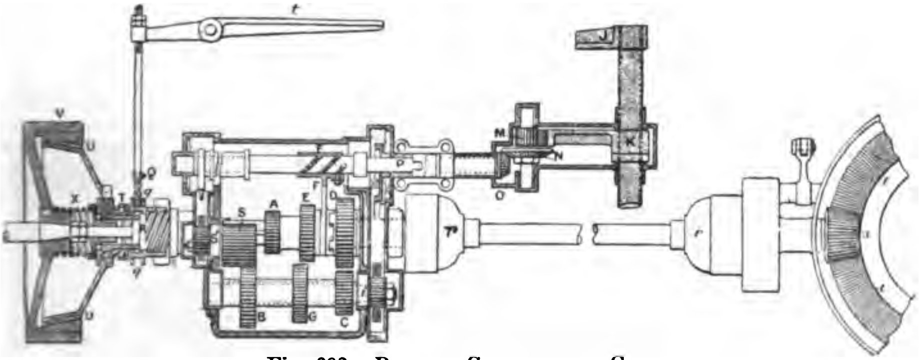


Fig. 392.—Renault Change-speed Gear.

The Renault friction clutch is worked by the pedal *t* and rod Q, Fig. 392. A chain passes round a groove in sleeve *q*, and its other end is supported by a tension spring fixed to the frame. Depressing the pedal turns the sleeve *q*, which has an internal worm screwing over a corresponding fixed worm; on turning the sleeve forces the male clutch cone U away from the clutch shell V against the action of spring X; a thrust bearing, T, is placed between the sleeve *q* and the clutch.

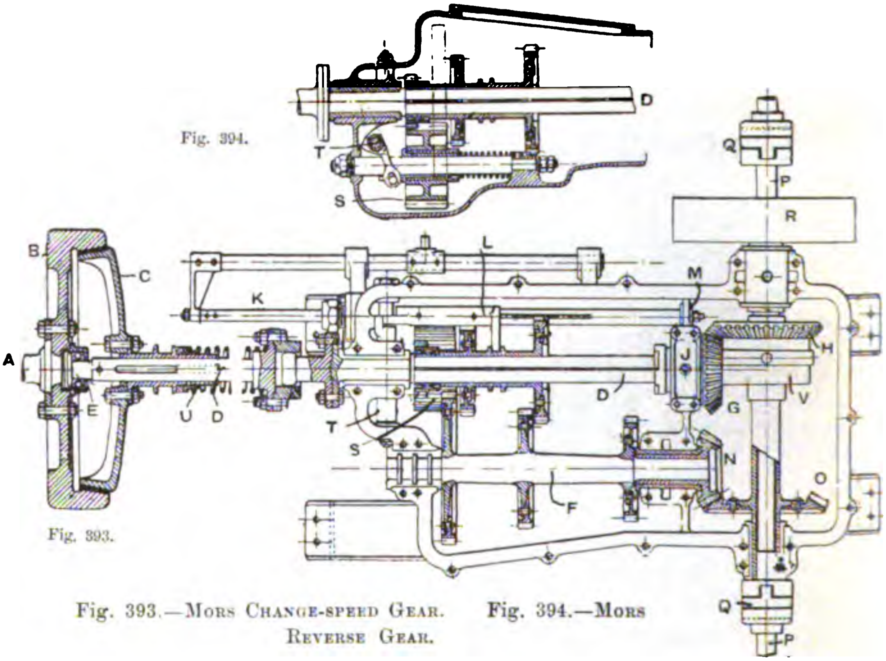


Fig. 393.—Mors Change-speed Gear.

Fig. 394.—Mors Reverse Gear.

The Mors transmission has the usual side chains, and the gearing gives the now customary direct through-drive on the top (fourth) speed. The motor shaft A, Fig. 393, carries the clutch shell B, the cone C of the clutch being carried by the main driving shaft D, which has a ball bearing in the clutch shell at E. Shaft D has three gear wheels on one sliding sleeve on a squared part, gearing with fixed wheels on the second-motion shaft F. At top speed the bevel gear G H in connection with the main shaft is driven through the coupling J, but this is put out of action and the sleeve of wheels is slid along when required by rod K, which operates fork L and connection M. At lower speeds the drive is from one shaft, D, to the other, F, and thence through bevels N O to the differential shaft P, which has couplings, Q, and brake drum, R. For the reverse there is a wide pinion, S, on an intermediary shaft (*see* also the detail, Fig. 394), brought into action by fork, T, the drive being transmitted through the second-motion shaft F. In Fig. 393 the portion of the driving shaft D, surrounded by the clutch spring U, is shown broken away. V is the differential.

The Cottereau change-speed gear is of the Panhard type, and the main shaft drives by bevel gearing a small cross-shaft which replaces the ordinary countershaft. At one side this shaft has a brake drum and on the other a sprocket, from which a chain passes to a sprocket ring on the differential gear of the live axle. There is but one chain, and there is a direct through-drive on the top speed. (The Belsize car (Marshall & Co.) employs a similar system.) This is the method employed in the 7- and 10-h.p. cars. In the 16-h.p. car the final drive is by two side chains from the usual countershaft.

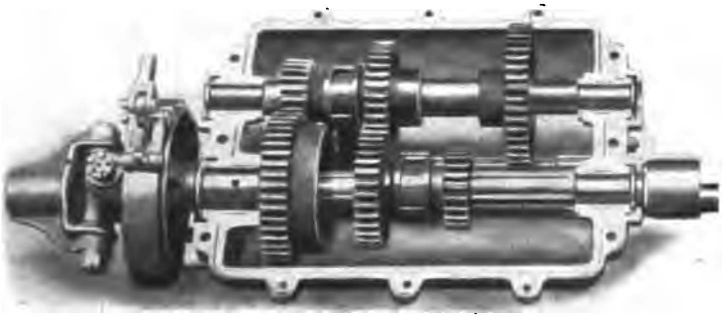


Fig. 395.—BENZ CHANGE-SPEED GEAR.

The Darracq car has the usual sliding gear-wheels, and there is a direct through-drive on the top speed; a longitudinal shaft drives a live rear axle through bevel gearing. The Benz gear (Fig. 395) typifies the same practice.

The Richard-Brazier change-speed gear with four forward speeds also gives a direct drive for the top speed, the first and second motion shafts being alongside each other. There is a flexible through-drive from the flexible coupling (which connects the gear with the main shaft) to the bevel wheel which drives the countershaft. From what has already been said in describing similar gears there will be no difficulty in understanding this. In other types of Richard cars, the transmission gear is more usual, being of the direct-drive longitudinal, universally jointed shaft type.

The Ader transmission (Fig. 396) gives a direct through-drive on the top speed. The attachment to the motor friction clutch is at A; and the direct-drive is through shaft A and through a jaw clutch to bevel wheel E on the differential of shaft F. For the lower speeds, motion is transmitted by the spur wheels G, H, J, mounted on a square formed on their shaft, to corresponding wheels K L M on the second-motion shaft N, and then through the bevel O to differential. The back face of spur-wheel J forms one part of the jaw clutch for the top speed. P shows the brake drum or pulley. The gears are changed by lever Q, shaft R, and fork S.

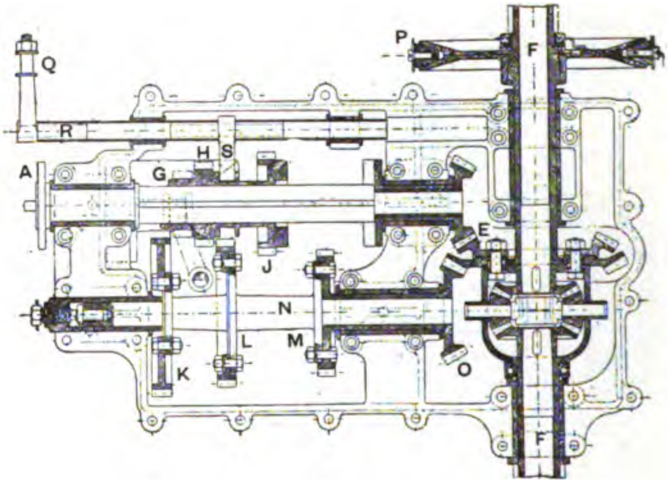


Fig. 396.—Ader Change-speed Gear.

The de Dietrich (Turcat-Méry) transmission is shown by Fig. 397. The fly-wheel A has a friction clutch B, with collar C driving the first-motion shaft; the two motion shafts D E are in the same horizontal plane, but there is no direct through-drive. The shaft D is not squared in the usual way, but four equi-distant slots are milled in it so as to form four projecting ridges, which engage in corresponding recesses in the hubs of the sliding spur-wheels, which it carries. This is a Panhard type gear and therefore does not need further description. The countershaft chain drives the rear wheels from side sprockets as usual. G is the reverse-motion gear.

The Brooke transmission and change-speed gear presents some novel features. The crank shaft lies across the car and carries a friction clutch, outside which and driven by it is a chain wheel. From this is driven by a Renolds chain the wheel A, Fig. 398. This gear is enclosed in an oil-tight aluminium case. B is the first-motion shaft and C the countershaft, this chain driving the rear wheels by end sprockets (not shown) as usual. The three fixed sprockets, D, E, F, on the first-motion shaft are connected by Brampton roller chains to three loose sprockets, G, H, J, on the countershaft C. By means of jaw clutches, any two opposite chain wheels are brought into operation. For reverse motion, chains are not used; a spur wheel K on the driving shaft B meshes with the intermediate pinion M, and this with the large spur wheel N, mounted on the differential shaft. Change of speed and direction are controlled by a lever which is rigid with a quadrant, this latter working into the toothed wheel

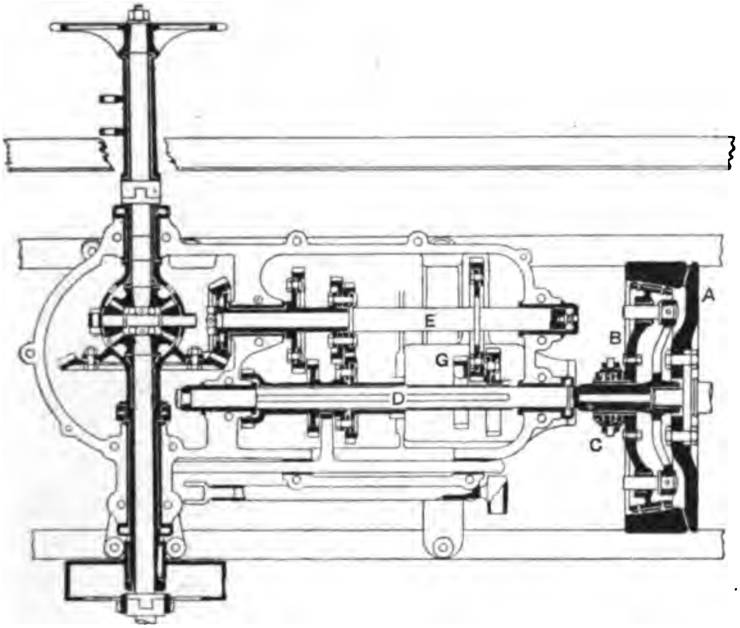


Fig. 397.—De Dietrich (Turcat-Méry) Change-speed Gear.

O, carried on the outer edge of the cam shaft P, which passes halfway across, inside the gear box. Shaft P carries the peculiar cam shown, and this is so shaped that, when rotated, it gives a longitudinal movement to one or other of two sliding rods, which pass across the gear box, and which carry steel rollers travelling in the cam grooves. The upper rod throws in and out the intermediate reversing pinion M, and controls the first-speed jaw clutch by the arm R; the lower rod controls the second and third speeds by arm S. The differential gear T is connected by a sleeve with the jaw clutches of the sprocket wheels G, H, J, and with the spur-wheel N, this sleeve also carrying a water-jacketed band-brake drum U, outside the gear case.

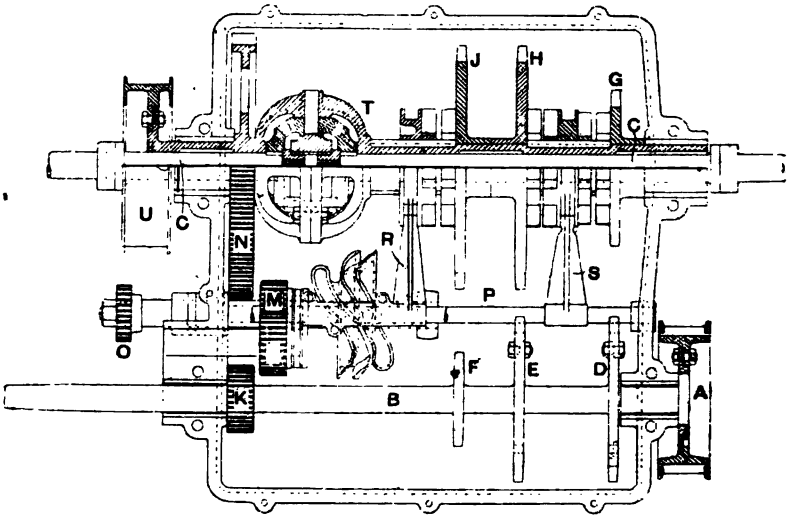


Fig. 398.—Brooke Change-speed Gear.

The feature of the Wolseley transmission is the chain drive between the motor friction clutch and the first-motion shaft of the change-speed gear. Fig. 399 shows the arrangement on the 7-h.p. and 10-h.p. cars. The right-hand pedal A^2 directly operates the friction clutch A^1, mounted on the motor shaft A; normally the clutch, which has a ball thrust, is held in engagement by a volute spring. A Renolds chain, shown, passes to a hollow sprocket, D, which is very wide to allow the sprocket on the motor shaft to move outwardly when the clutch is disengaged, and to allow of the chain running straight at all times; another reason for the extra width is the sideway movement given to it when the speed is changed from one gear to another, since it is mounted to revolve freely upon a large brass bush on the first-motion shaft. It has square jaws, which project inwardly and engage normally with corresponding jaws formed on a boss rigid with the shaft D. A guide carries the sprocket in such a manner that its internal jaws can be brought in and out of engagement with the first-motion shaft, the guide being controlled by cam B^1, mounted on the gear-change shaft B. The guide is carried on the end of a stationary rod, C, passing across inside the gear box, and which also serves as an internal guide for the sliding sleeves operating the change-gear wheels themselves. The cam is so shaped that the jaw clutch inside the sprocket comes into engagement just after each spur-wheel has been brought into mesh in the gear box, and similarly in disengaging just before either of the spur-wheels is slid out of

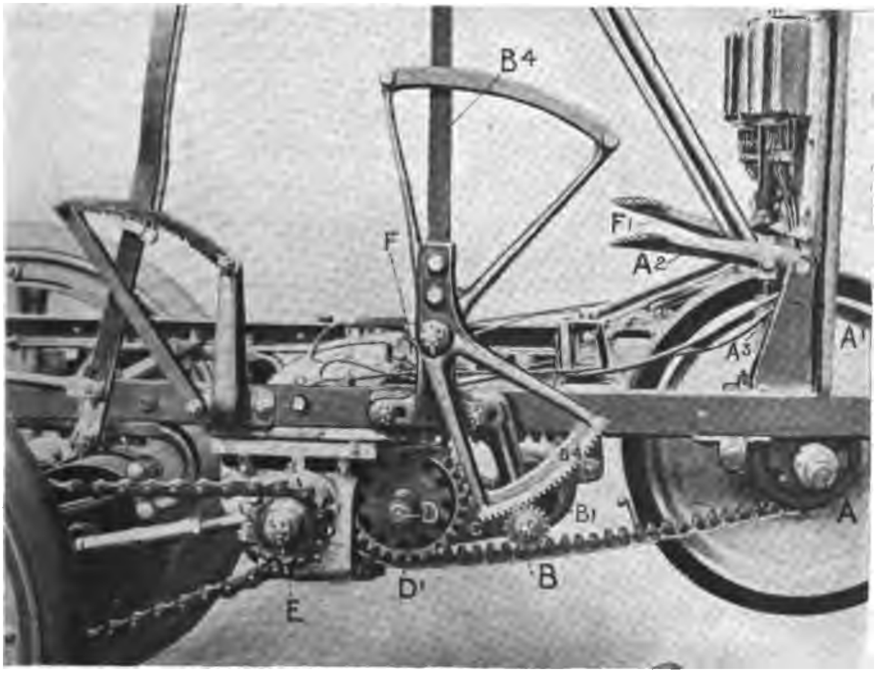


Fig. 399.—Wolseley Transmission Gear.

mesh; this arrangement avoids extreme shock and strain on the gear teeth. The change-speed gear is operated by the lever B^1, bolted to which is a quadrant gearing with the spur-wheel B^2. In the actual gear box is a long cam drum, which operates sliding forks; these bring sliding spur-wheels on the first-motion shaft in and out of engagement with corresponding wheels fixed on a differential countershaft; the differential has spur, not bevel, gears.

The means for lessening shock and strain in speed-changing employed on the Wolseley 20-h.p. cars differ from the above, and the result is said to be even more successful. The horizontal motor has two friction clutches (one in each fly-wheel); two chains, one each side of the car, drive the first-motion shaft. A two-way jaw clutch is employed, its sliding portion being mounted on and otherwise rigid with the differential gear. It engages spur-wheels either to the right or left of the differential, according to how it is moved, and these spur-wheels are mounted freely on sleeves and are made rigid with the differential only through the jaw clutch. This last is operated by the composite cam drum that slides the gears into mesh. The action then is as follows: Whenever the friction clutches engage with the fly-wheels, the Renolds chains drive the first-motion shaft; the sliding wheels on this shaft are brought into gear much as usual with the corresponding wheels on the countershaft, but these latter wheels cannot drive the countershaft until the change of speed has been quite completed and the jaw clutch has come into use. For the reverse, intermediate wheels are slid into mesh; in the gears on the lower power cars mentioned above, wheels on the first-motion shaft are themselves slid into gear with the intermediate ones.

The change-speed gear employed on the Rochet 6½-h.p. light car differs only in small details from the gears employed on other cars of the same make. The gear is shown diagrammatically by Fig. 400, and gives a direct through-drive on the top speed. The upper shaft A is driven through the friction clutch B, and carries the sliding train of toothed wheels C D, gearing for the lower speeds with a similar train E F on the underneath shaft H. The gear wheels E F on the latter are slid out of engagement when the car is running at top speed, so that shaft H is still, and does not even revolve idly. The gears are each shifted by a fork, that, J, for the wheels C D on shaft A being a fixture with rod K; whereas the fork L, operating the wheels on shaft H, slides freely on rod K, and is kept pressed against

J by the spiral spring indicated in section by M. Thus spring M constantly forces the train F N to the left (E, it may be said, is fixed to shaft H); but two opposite causes act alternately, that is, L is stopped by J, whose position depends on that of the train C D, and in the second place it cannot go beyond the squared portion of the shaft H. In its extreme left position N engages with P, which is mounted on a sleeve Q, loose on the shaft A, and the continuation of this sleeve to the right is the actual driving shaft. In explanation of the action of this system, it may be said that working the rod K causes C on shaft A to drive E on shaft H; the power is taken through N to P, and thence to the live axle; this is the lowest speed. When D gears with F, and N with P, the second speed is obtained; for the top speed the jaw clutch R directly connects the wheels D and P, and there is a direct drive from motor to wheels; the fork J pushes fork L and train F and N to the right and out of gear, so that shaft H does not revolve. For reverse motion, C, on shaft A, is slid to the left until it drives S, mounted on an intermediary shaft, T; at the same time the rim of wheel D bears against the cheek of wheel U, which thus is pushed to the left until it drives wheel E; N being by this time in gear with P, the reverse motion is transmitted. A spring, W, between S and U, prevents U engaging except when compelled to do so by the pressure of D.

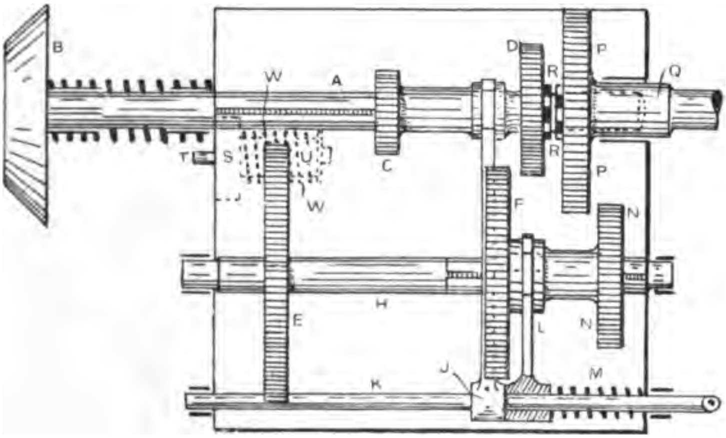


Fig. 400.—Rochet Change-speed Gear.

In many of the Panhard type gears above described, the counter-shaft has been at the rear of the change-speed box, between it and the rear axle. In the Belgica system, however, the countershaft is in front, and forms a support for the gear-box. A universally jointed longitudinal shaft connects the clutch with the change-speed gear, and the final drive is by side chains.

The de Dion-Bouton three-speed and reverse gear is on the lines of their old two-speed gear, and is fitted to cars of 8 h.p, and less. It employs a duplex expanding clutch, which has been a feature of previous de Dion-Bouton gears. The gear is shown in longitudinal section by Fig. 401, and in cross section by Fig. 402. The main shaft A is directly driven by the motor shaft, and carries two spur-wheels, K F, K running loosely on the shaft, while F is fast on it. Between these wheels is a sliding sleeve pinion, B, which revolves as one with shaft A by means of three feathers. The striking fork 3 3, actuated from the steering pillar, moves the sliding pinion B to three positions on its shaft: (1) in mesh with the toothed ring C^1 on the clutch box C; (2) to the left, clear between the wheels C^1 and K; (3) further to the left, in mesh with internally cut teeth on the right-hand and smaller ring B^1 of the loose-gear wheel K. The three speeds and the reverse are

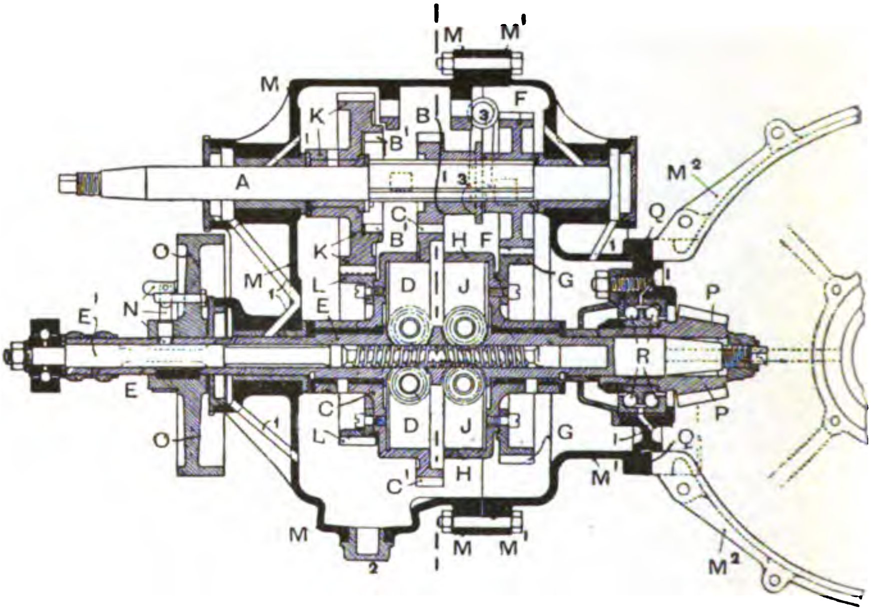


Fig. 401.—De Dion-Bouton Change-speed Gear.

obtained by working a horizontal clutch lever and a smaller lever, which moves on a three-notch sector placed on the steering column. For obtaining the first speed, the small lever is put in the first notch on the extreme right, and the gear lever is pushed forward; then pinion B meshes with the toothed ring C^1 on clutch box C, and the clutch expands within the box, so that the countershaft E is driven. For the second speed, the position of the small lever is unimportant; the clutch lever is drawn back so as to expand the clutch I, in clutch box H. The drive from main shaft A then is conveyed to the countershaft E through toothed wheel F, which meshes with toothed ring G, firmly bolted to the clutch box H. The expansion of one clutch contracts the other, so clutch D, being withdrawn from contact with its box C, and as sliding pinion B on main shaft A only drives the gear connected with the left-hand clutch box, its position can be disregarded when the clutch lever is drawn right back. For the third speed, the small lever is moved to No. 3 notch (extreme left), which causes sliding pinion B to engage as a positive clutch with the internally toothed ring B^1 on wheel K, so that K rotates at the same speed as main shaft A. Then the clutch lever being pushed forward, clutch D is expanded until it drives the countershaft E, by means of pinion K, positively clutched to shaft A, and by means of the toothed ring L, bolted to left of clutch box C, the teeth of the ring meshing with the teeth of pinion K. For the reverse, the clutch lever is moved to its middle position; then neither of the expanding clutches is in contact with its box, and the small lever is then moved to the No. 2 or central position in its sector. This causes sliding pinion B to slide on shaft A to a position between the wheels C^1 and K, but neither meshing with the former nor clutching with the latter. Upon

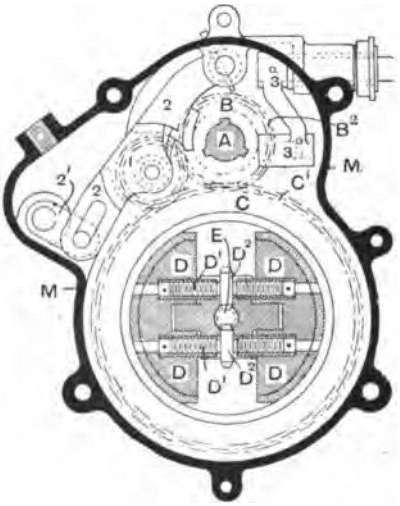


Fig. 402.—De Dion-Bouton Change-speed Gear.

the reversing lever being turned over, the wide pinion 1, Fig. 402, rotating freely on a stud on the rocking arm 2, by the movement of the lever arm 2^1, with which the reversing lever is connected, is caused to engage with pinion B and toothed ring C^1 on clutch box C, so that when the clutch D is expanded by the forward movement of the clutch lever, the countershaft E is rotated in a direction opposite to that for forward speeds, and the car is driven backwards.

This new gear enables the car in motion to be prepared for any subsequent speed. Assume that the car is running on its second speed, the driver can move the small lever to either the first or third speed notches, as may be necessary. When stopped in a block of traffic, he can move the small lever to notch 2 on the sector and turn over the reversing lever, and so be ready to go backwards immediately by thrusting the clutch lever forward, or to go forward on the second speed by drawing the clutch lever backwards. When the clutch lever is drawn back, the drive passes through the second-speed gearing; thrust forward, the drive passes through the first speed or the third speed, according to whether the small lever is in notch 1 or 3; and through the reversing gear when the small lever is in notch 2, and the reversing lever is turned over.

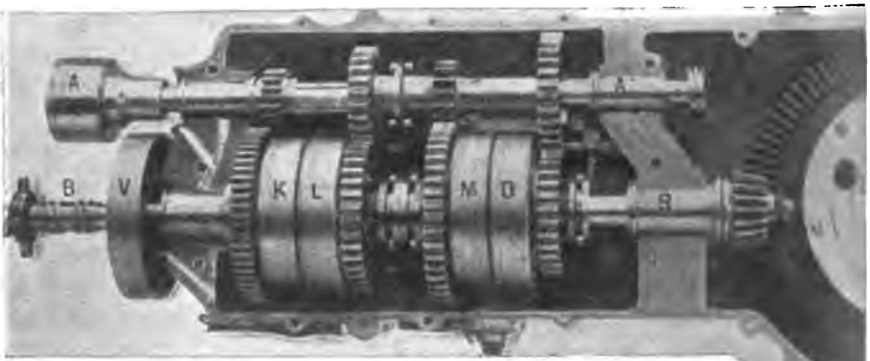


Fig. 403.—De Dion-Bouton 10-h.p. Car Gear.

In further description of this gear, it will be seen from Figs. 401 and 402 that the countershaft E is hollow, and accommodates the change-speed rack E^1, suitably connected to the clutch lever referred to above, and by its means moved in and out of the gear case, so that the coarse pitched square thread E^1 serves as a rack to rotate the spindles D^1, also its rotation adjusts one or both of the expanding clutches D; I in relation to the inner surfaces of their respective clutch boxes. The rack is prevented from rotating normally by a locking bolt, N, which drops into the uppermost of two slots formed on opposite sides of the rack, and indicated by the dotted lines. When desired, bolt N is raised clear of the slot by the pivoted lifting trigger at its upper end. The gear box is in two parts, M M^1, flanged and bolted together. The differential gear case M^2 also is flanged and bolted. The right-hand end of the hollow countershaft E runs in the double ball-bearing R, and beyond this bearing carries the driving bevel pinion P, which is drilled taper, and is keyed with feathers to the tapered end of the countershaft by a large nut. The double ball-bearing R is carried in a disc, Q, secured between the flanges of the gear box M^1, and the differential case M^2.

The three-speed and reverse gear employed on the 10-h.p. de Dion-Bouton cars closely resembles the above, but it contains more parts (see Fig. 403). The first-motion shaft A lies above the second-motion shaft B, the latter transmitting power to the differential by means of the bevel wheels shown to the right. The differential shaft occupies the centre of the big bevel wheel. The shaft B carries two expanding clutches, whose expanding portions do not slide along the shaft, but the shells K, L, M and O, with all the spur-wheels on both of the shafts, can be moved longitudinally together. When moved forward to the left, the clutch shells L and O are brought outside the expanding clutch members, but when moved backward, the expanding members will be inside the shells K and M. Each spur-wheel is in mesh with a spur-wheel on the second-motion shaft. One controlling lever operates the clutches, and another slides the gear wheels backwards or forwards in the box. When shell K is made rigid with the second-motion shaft, the reverse gear comes into use, an intermediate pinion connecting the spur-wheels on the two shafts. By holding the shells M, L and D, the first, second, and third speeds respectively are brought into use. A band brake, V, is fixed outside the gear box on the forward end of the second-motion shaft. The power is transmitted from motor to gearing by a longitudinal shaft with flexible couplings, and from the gearing to the rear wheels by Cardan axles.

The R. de Metz speed-changing apparatus, Figs. 404 to 406, was applicable to light cars and motor cycles. The motor shaft A has screwed to its end the piece B containing channels which convey oil from the lubricator H to the various parts. Keyed on B is clutch coupling C, which, by moving the fork R, the driver can isolate for disengagement, bringing it successively into contact with pinions D and E for slow and full speed respectively. When it gears with E, the motion of the shaft A is transmitted directly to pinion K mounted on the same hollow shaft as pinion E. When, on the contrary, the coupling C forms one with the pinion D, the latter drives pinion E by aid of the large pinion D^1 under pinion Q, both of these being keyed on the shaft M, thus driving pinion K also; but motion is transmitted only after undergoing two demultiplications. Fig. 406 represents the collar by means of which the demultiplicator is fixed to the big tube behind the tricycle at the required point in the transversal direction. Regulation in height is operated by aid of a

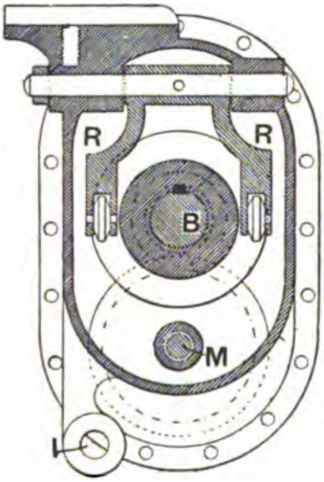


Fig. 404.

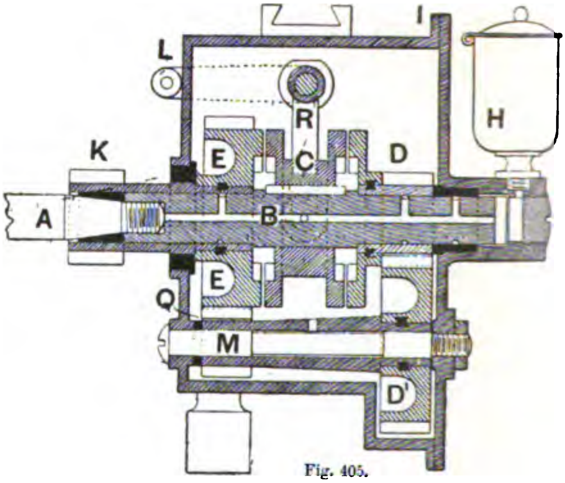


Fig. 405.

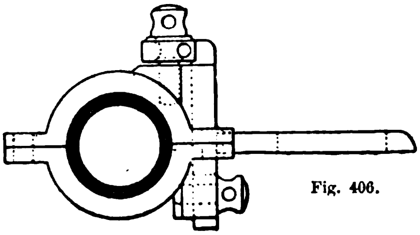


Fig. 406.

Figs. 404 and 405.—Sections of Metz Change-speed Gear. Fig. 406.—Collar for Fixing Demultiplicator.

dovetail piece governed by the screw I, shown at the base of Fig. 404.

Of the Ariel two-speed gear for tricycles and quads, Fig. 407 is an elevation, Fig. 408 a section, and Fig. 409 a view of the lever for changing gear. A is the motor shaft, a square portion of which carries a clutch sleeve, B. Two pinions, C and D, revolve freely on the shaft, or either can be held at will by the sleeve B, by means of jaw clutches. Parallel with the motor shaft A is a countershaft E, carrying pinions F and G, both keyed to the same sleeve, which revolves freely on the countershaft, the two pinions F and G being always in mesh with pinions C and D on shaft A, the pinion C driving a large spur wheel on the axle of the tricycle or quadricycle. It will be seen when the sleeve B holds pinion C the motor is driving direct on to the large spur wheel on back axle; this, being the largest pinion, therefore gives the high speed. By connecting pinion D to the motor shaft A by means of sleeve B pinion C revolves freely on shaft A, but is driven by D, through F and G, thus giving the slow speed. When sleeve B is midway between the pinions C and D the motor itself is disconnected, so that the machine can run down hill by the force of gravity alone, and will leave the motor free. All the pinions being constantly in mesh, it is an easy matter to change the gear, pinions

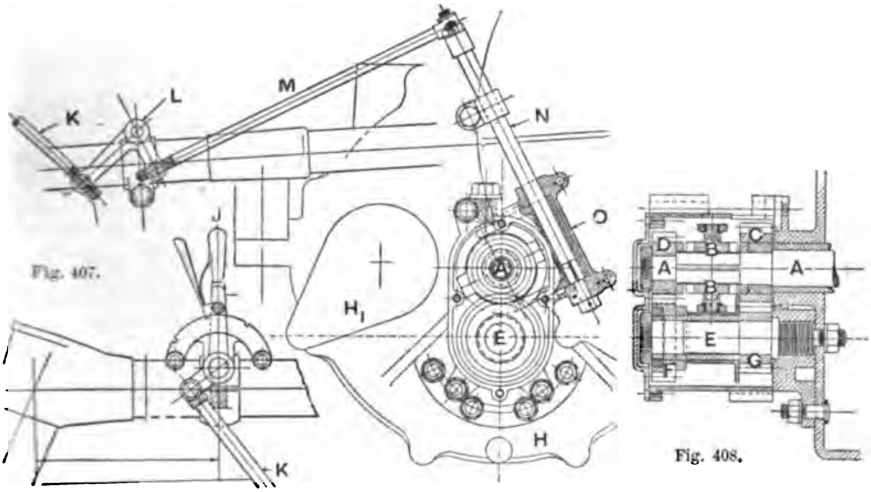


Fig. 407.

Fig. 408.

Fig. 409.

Figs. 407 to 409.—Ariel Tricycle Change-speed Gear.

C and D running only at a slight variation of speed. In Fig. 409 is shown the lever, J, for changing gear, which is fitted to left front of top tube on the cycle frame. In its upright position, as shown, the motor is out of gear. Moving the lever J to the front notch engages the high gear, and the reverse movement the low gear. The lever J moves the rod K (shown in Fig. 407 and continued in Fig. 409), which in its turn shifts the bell crank L, working on a stud on the lower central frame tube. L transmits the movement to M, which in its turn shifts the arm pillar N in the socket O. The short striker at the base of N moves the clutched sleeve B to right or left as required.

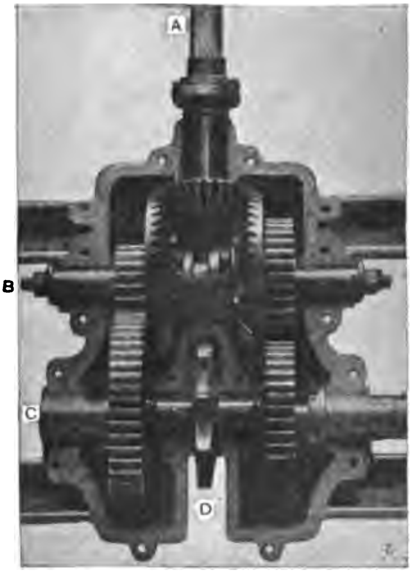


Fig. 410.—Protos Change-speed Gear.

The Protos (German) change-speed gear is shown in plan by Fig. 410. The short shaft A carries one member of the friction clutch, and the final drive is by chain from the sprocket D to a sprocket ring surrounding the differential on the live rear axle. The gear gives two forward and two reverse speeds. The short shaft A ends in a small bevel, shown, and this drives in opposite directions the two larger bevels which are quite free on the first-motion shaft B. On the shaft between the bevels is a two-way jaw clutch, working on a feather key, and this clutch can be slid to right or left to engage with jaws carried by the bevels, so as to lock either bevel to the shaft. Thus, by locking one bevel the shaft rotates in a certain direction, and on locking the other and releasing the first, the shaft rotates in the opposite direction. Outside each bevel, and fixed to the shaft B, is a spur-wheel meshing with a corresponding wheel on the second-motion shaft C. The second set of spur-wheels can be slid in and out of engagement by a hand lever. The second-motion shaft C carries a central driving sprocket, D, which provides for the chain drive to the live rear axle, as mentioned above. Thus, when the shaft A is being driven by the motor, the shaft B can be made to rotate in either the forward or reverse direction. Both of its spur-wheels revolve with it, and for the lower speed the two left-hand wheels are caused to gear with each other, and for the higher speed the two right-hand wheels. Then the sprocket D transmits the motion.

The Montauban-Marchandier block transmission devices are of a form that facilitates mounting of the car. The three-speed block-transmission gear (Fig. 411) has inside an aluminium case five pairs

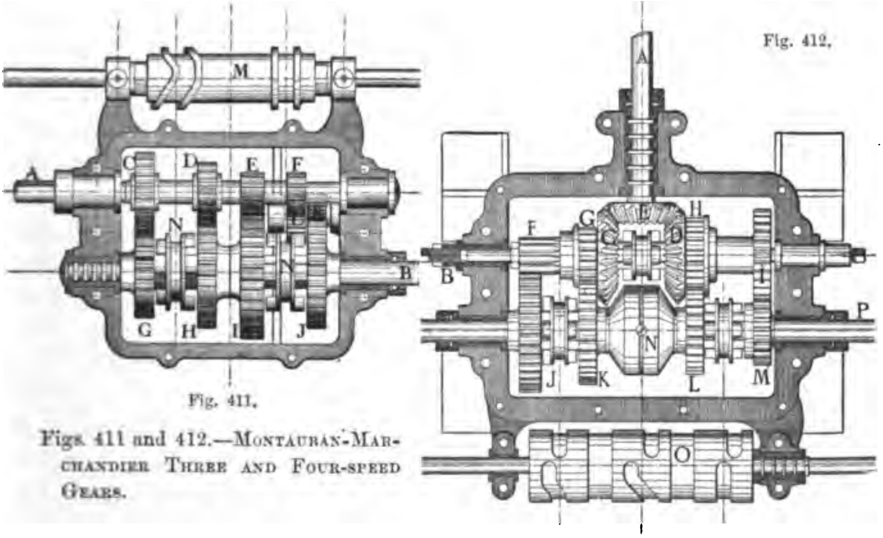


Fig. 411.

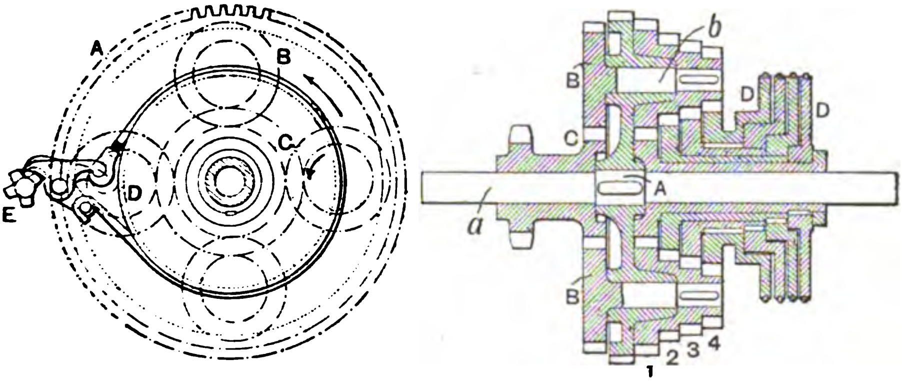
Fig. 412.

Figs. 411 and 412.—Montauban-Marchandier Three and Four-speed Gears.

of toothed wheels, which give three speeds and retrograde motion. The shaft A, united to the motor by a sleeve, has four toothed wheels, C, D, E, F, gearing with four wheels, G, H, I, J, loose on shaft B, which is parallel with A; B also has two tenon sleeves, N, which move laterally under the action of forks worked by a curve traced on a roll, M, which in one revolution causes alternate displacement of the forks, and consequently of the tenon sleeves. The tenon sleeve that is pushed to the right or left comes into contact with the sockets of the wheel towards which it is pushed, and thus renders it interdependent with the shaft B at the speed corresponding to the relation of the wheels of the couple thus engaged, the other wheels turning loose on shaft B. For retrograde motion the wheel F gears with an intermediary pinion L, keyed on the hub of a second pinion K, which is geared with wheel J, these two pinions reversing direction of rotation of wheel J. The shaft of roll M is prolonged to the right and left according to the installation, and carries a pinion with which gears either a toothed sector or a rack worked by the driver by aid of a hand lever. The enclosed gear works in an oil bath.

The Montauban and Marchandier four-speed gear (Fig. 412) has an aluminium case containing three shafts: the first one, A, is a prolongation of the motor shaft, and the second shaft, B, is parallel to the axle of the driving wheels, and is furnished with two loose bevel wheels, C D, moved by a third wheel, E, forming one with the shaft A. These three wheels turn as long as the friction clutch is tightened. Between the two wheels C D, furnished with sockets, is a sliding sleeve which has tenons running along shaft B, and according as these tenons enter the wheel to the right or the left forward or backward motion is obtained. On each side of the bevel wheels C D, and on the same shaft B, the keyed spur wheels F, G, H, I, gear respectively with J, K, L, M, and give four speeds. Between each couple of wheels J K, and L M, mounted loose on the differential case which covers shaft P, and entrained by them, is a sleeve pushed to the right or to the left; on the wheels are corresponding sockets. The lower shaft P is in two parts, and constitutes the differential N, which is enclosed, automatically and copiously lubricated, and protected against dust. Each part of this shaft P is prolonged on either side of the block (passing through compressed leather boxes retaining the oil), and has a sprocket wheel at its extremity, or in some cases an ordinary toothed wheel, which definitely transmits motion to the rear driving wheels. Each tenon sleeve is entrained by a fork worked by a special curve fixed on cylinder O, on which are three curves causing successive gearing and ungearing of each couple of wheels. Less than one revolution suffices to pass from stoppage to the greatest speed, then stop and run backwards. The driver works the cylinder by aid of a rack and pinion and hand lever or other simple means. All the gear, shafts, etc., run in oil.

The Prétot fore-carriage introduces quite a different system from ordinary toothed gear transmissions. In Figs. 413 and 414 *a* is a motor shaft, or, more rarely, a secondary shaft connected with the motor shaft by toothed gearing or belt, giving a first reduction of speed which, moreover, is constant. Wheel A is keyed upon it, and if toothed it imparts the motor shaft motion to shaft *a*, which in that case is secondary. Each of the four wheel naves receives an axle *b* parallel with the shaft *a* and interdependent with a planetary pinion B gearing with the toothed nave C, loose on the central axle. This nave forms one with a pinion carrying the endless chain which imparts motion of crown wheel A to the differential. For this latter purpose a set of pinions is keyed on each axle *b*, all cast on 1, 2, 3, 4 respectively gearing with loose wheels on shaft *a;* though these last can be in turn immobilised by bands forming brakes around discs D, which form one with the wheels. Four cams, E, are each placed opposite discs D and fixed on a lateral shaft which can be turned by means of a toothed pinion and rack. These cams tighten the brakes by aid of the device shown to the left of Fig. 413. When one of the wheels is thus fixed, while wheel A turns and drives axle *b*, the pinions geared with this wheel also will turn and cause rotation of pinions B, nave C, and the endless chain pinion. Suppose that gear 3 is engaged; as represented by Fig. 414, its wheel is larger than nave C and its pinions are smaller than pinions D; when wheel A turns in direction of the arrow (Fig. 413) (forward motion) the nave C will be driven in the same direction with a speed proportional to the difference of the number of teeth of the wheels on the same axles. The same result is obtained when gear 4 is brought into action, the car then running forward, but with greater speed than before. In gear 2, the wheel and pinion of which are of the same diameter as C and B respectively, there is no difference between the number of teeth of the wheels on the same axles; nave C remains motionless and the car is stopped. Finally, when wheel 1 is geared, its diameter being less

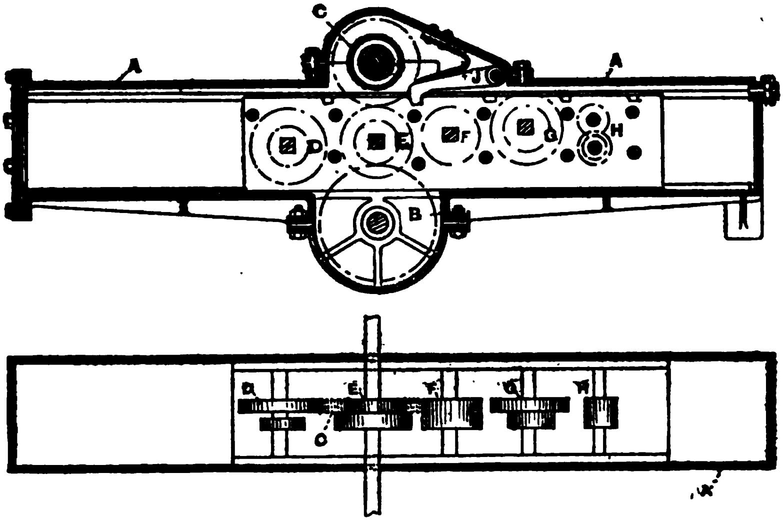


Figs. 413 and 414.—Prétot Toothed Transmission Gear.

than that of C, wheel A continues to rotate in the direction of the arrow, whilst the nave C is driven in the opposite direction; then the car moves backwards. Mere displacement of the rack, which causes rotation of the shaft of cams E, thus gives changes of speed, stoppage, and reversing of motion.

In the Louet change-speed system the gear wheels, instead of sliding into mesh, engage directly on the face of the teeth. A gear wheel, B (Fig. 415 and 416), is driven by the three-cylinder vertical motor, and above it is the gear wheel C, mounted upon the countershaft, the wheel centres being in one vertical plane. On one side is another gear wheel, D. The change-speed change wheels D, E, F, G and the reversing pinions H are carried in a frame sliding lengthwise in the gear box A, and are actuated by the usual side lever. At the top of the box the pawl J falls into a notch in the frame, and locks the gears in position until a change is required. For each speed there are two unequal wheels, excepting F, which is double the width of the others. The first speed is obtained by the driving wheel B gearing into the small wheel of D, whose larger wheel drives C. The shaft of C carries the differential gear and side chain sprockets. The second and fourth speed gears E and G operate in the same way, but the third speed wheel F slides directly in between B and C, whose ratio is not thereby altered. For the reverse pinions H are slid into mesh with B and C.

The Méran-Gervais change-speed gear is novel. Various gear trains are mounted upon a disc which can be rotated about its axis. The motor shaft and the driving shaft are in line, and on their inner ends, which face each other, are jaw clutches which can be brought nearer to, or taken farther away from, one another by a vertical handle operated by the driver. These jaw clutches fit into similar clutches carried by the various gear trains on the rotating disc; and by the means of this disc any desired train can be introduced between the forward end of the motor shaft and the rear end of the driving shaft. A direct through-drive on the top speed is obtained by substituting for a gear train a short shaft having a jaw clutch at each end; this short shaft is carried by the rotating disc and brought into action in the same way as the gear trains. It will be understood that the top-speed drive is through the motor shaft; first, jaw clutch, short disc-carried shaft; second, jaw clutch, main driving shaft, and thence through bevel gearing to the differential on the live rear axle. The arrangement of the differential for varying the gear ratio between road wheels and motor is another new feature. The differential gear casing is so arranged that the contained gear and the bevel wheels that drive the axle can be bodily removed. Two short shafts, not the actual axle, are driven by the differential, and these carry spur-wheels close up. The two halves of the live axle terminate inside the central casing, and their ends carry other spur-wheels which mesh with those on the short shafts. All these spur-wheels are easily removable, so that they can be replaced with wheels of different proportions and the gear ratio thereby changed. This convenience, of course, involves extra friction losses consequent upon the introduction of the four extra gear-wheels.



Figs. 415 and 416.—Louet Change-speed Gear.

The Swift two-speed gear is shown by Fig. 417. The motor drives a small spur-wheel in mesh with a larger one, this forming the simplest possible speed-reducing gear, and the shaft of the second spur-wheel drives a longitudinal shaft through a friction clutch and universal joint. The change-speed gear is wholly mounted around the live rear axle I, and is enclosed in an aluminium casing, A. The short shaft P is driven as described by the motor, and it terminates in a bearing in the central casting, which rides freely about the rear axle, this latter being solid from end to end. The casing A is in two parts, and is rigid with the tubes, which pass from it to each of the brackets carrying the rear springs; inside these fixed tubes the live axle runs freely. On the driving shaft P are mounted freely two small bevel wheels, R, T, and either can be made fast to it by means of a two-way jaw clutch, S, operated by a lever. A ball-thrust bearing, L, on the shaft takes the thrust of the bevel wheels R, T; these two always mesh with the larger bevels

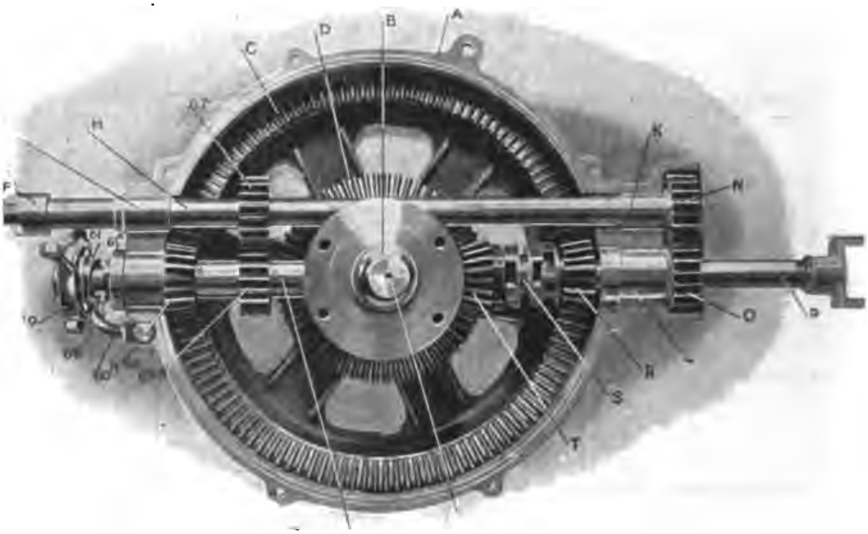


Fig. 417.—Swift Change-speed Gear.

C D respectively, and D is rigid with the live axle I. When the bevel R is clutched to shaft P it drives C, and gives a low speed. When, however, T is clutched to the driving shaft, the wheel D is driven, and the high speed obtained. A differential is dispensed with; instead, in the hub of each wheel is a pawl and ratchet device; these spring pawls, carried by the wheel, engage in internal ratchet teeth in a casting keyed to the axle, and serve to transmit the power to the wheels, and there is no difficulty, when turning a corner, for the pawls of one wheel to over-ride the ratchet teeth. This gives a free-wheel action to the car, which can obtain a greater speed downhill than the motor alone could give. This construction has the advantage of rigidity and cheapness, but the brakes on the wheels must be thoroughly reliable.

This gear also provides a means of communicating the motion of the starting handle to the motor, and a means of reverse motion. The starting handle fits a shaft, H, which revolves in bearings G, K, the starting clutch being shown at F. Toothed gears N, O transmit the motion to the motor through shaft P, whilst the driving pinions, R T, are of course out of gear. For reverse motion, the shaft P drives H, through pinions N O, and pinions 67 and 67A take the motion to short shaft E, which revolves in bearings. The bevel pinion 68 is free on this shaft, but when the reverse is required it is clutched to it by means of the clutches 61 and 61A, and lever 60, 60A. The forward speed clutch S is put out of engagement, and the axle is then driven in the reverse direction, for though shafts E and P revolve in the same direction, the bevel pinion 68 is at the other side of the centre to the pinions R, T. The locknut to the outer bearing of shaft E is shown by 69, whilst B is the ball race for the driven axle. This is a particularly neat and simple device, well adapted for light cars with live rear axles.

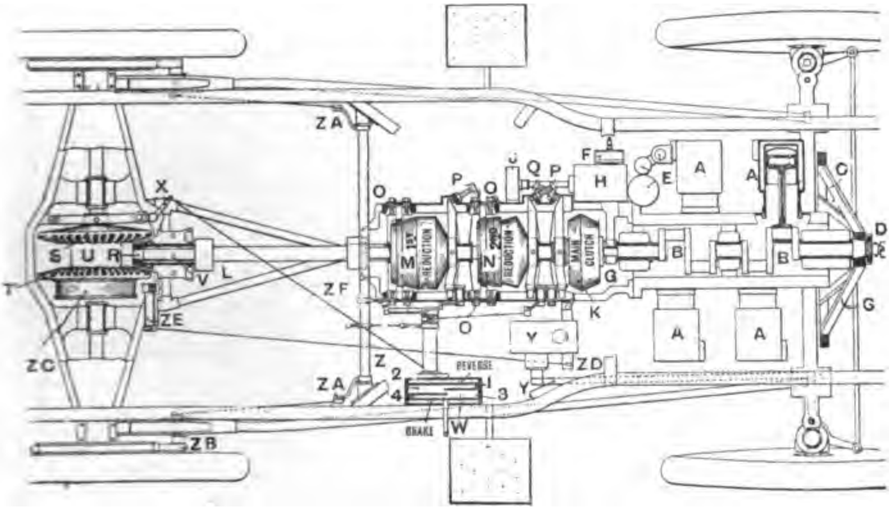


Fig. 418.—Wilson and Pilcher Transmission and Change-speed Gear.

The Wilson and Pilcher transmission gear differs from any other modern transmission system. It is shown in diagram by Fig. 418, which represents the four pistons of the horizontal balanced motor (*see* p. 270) driving a crank shaft, which is in the line of the power transmission when the car is running on the top (fourth) speed. K shows the main clutch, whilst M and N are boxes containing respectively the first and second speed-reduction gears, which are new devices based on the combination of a friction clutch with the epicycloidal or Crypto gear. Box M gives the third speed, that is, the first reduction of speed from the top speed (at which there is a direct through-drive). Box N gives the second speed. The lowest speed is obtained by combining the actions of the gears in the two boxes. Speed is changed without withdrawing the main clutch. The letter references in Fig. 418 may now be explained. Dealing with the motor, A shows the four cylinders; B the cranks with their shaft carrying the very big and heavily rimmed fly-wheel, C, with raking arms; D is the starting handle; E carburetter; F commutator; G helical gear drive to pumps; H lubricating oil pump; and J water pump. With regard to the transmission gear, K is the main clutch; L the universally jointed driving shaft; M and N first and second speed-reduction boxes with adjustment bolts, O, and further adjustment screws, P (the main clutch is adjusted by screw Q); R is the bevel pinion on the driving shaft engaging with either the forward speed bevel S or reverse speed bevel T, which surround the differential: U and V are the roller bearing for the bevel pinion R. The speed-

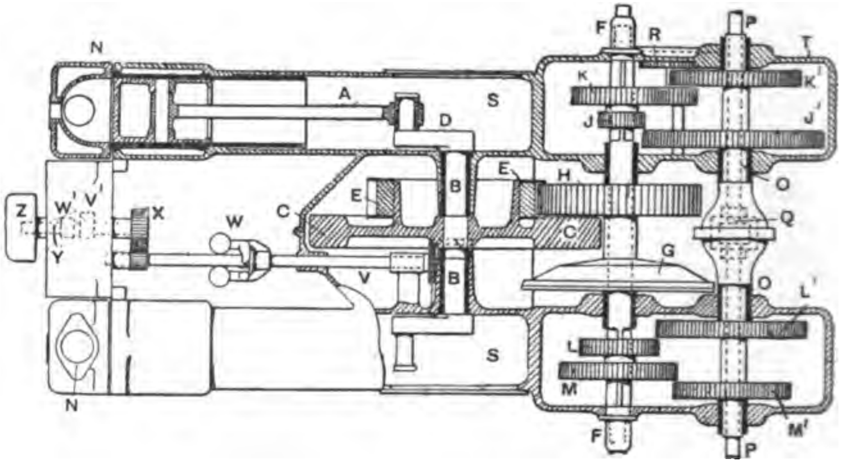


Fig. 419.—James and Brown Change-speed Gear.

changing quadrant is shown at W, and from this there is a connection to the lever X, which, by throwing bevel S out of gear with the pinion R, and putting bevel T in gear with the pinion, causes reverse motion. The steering gear and connecting rod are shown by Y. With regard to the brake system, Z is the brake-shaft with connections Z A to the side drums Z B; the internal brake drum is shown by Z C, and its actual pedal by Z D, which has a connecting lever, Z E. There is an automatic clutch release, Z F, to the brake action..

The Bardon transmission necessarily differs from usual practice owing to the employment of a balanced motor, whose countershafts, one on each side, run parallel with the side members of the frame. Each shaft terminates in a bevel gearing with a common countershaft. (In Fig. 716, p. 666, F is the crankshaft and G the first-motion shaft, and the following letters refer also to this figure.) A special toggle device operates a double-cone clutch, H, carried by the first-motion shaft. This clutch has four friction surfaces, and is arranged so as not to impose thrust strains on the shaft. The clutch causes a sleeve, carrying the sliding gear wheels, to become rigid with the countershaft, or stationary about it. The second-motion shaft, J, which chain-drives the road wheels, carries the differential, whose outer portion is rigid with four spur-wheels, and which has a sleeve passing to the brake drum, K; the spur-wheels mesh with others on the first shaft, G. The sliding gears are operated by two independent sliding rods.

The James and Browne transmission and engine gear form one independent piece of mechanism. The motor has two horizontal cylinders in the front of the car, and the connecting rods A (Fig. 419) work the crank shaft B, on which is the fly-wheel C. N shows the combustion chambers and motor cylinders, and S the crank chamber. The overhang cranks D are parallel with each other. Thus the fly-wheel C and the buffoline spur-wheel E are between the cylinders. A composite aluminium case T encloses the crank chamber and change-speed gear. The first-motion shaft F is driven through a special clutch, G (*see* p. 372), by spur-wheel H meshing with the buffoline wheel E. On one side of the clutch are the first and third speed sliding wheels J, K, which can be made to engage with J^1 and K^1 respectively; on the other side are the second and fourth speed wheels L, M, engaging when required with L^1, M^1 respectively. The driven wheels mentioned are carried on sleeve O of countershaft

P, this sleeve being connected to the differential casing and brake drum Q. For reversing, the intermediate spur-wheel R can be brought in play. Outside the gearing on the countershaft are couplings and sprockets, the latter chain-driving the rear road wheels. Mitre wheels U, on the crank-shaft B, drive the shaft V, on which is the motor governor W, and which, by spur gearing X, drives the cam shaft Y; on this shaft is the exhaust cam, V^1, the inlet cam, W^1, and the commutator Z.

In the Hermes transmission gear, the crank-shaft lies transversely, and the fly-wheel is in nearly the centre of the car. The usual

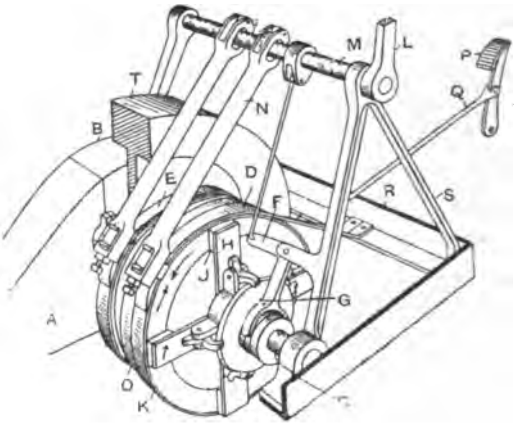


Fig. 420.—Oldsmobile Change-speed Gear.

cone clutch transmits the power through a flexible coupling to the first-motion shaft, which is in the same horizontal plane as the second-motion shaft. The wheels on the former are rigid with it, and those on the latter are mounted freely, but the shaft is so shaped by slotting that any one of the wheels can be made rigid with it by sliding it along; and for this purpose the hubs of the gear-wheels have spring catches, which engage with slots in the shaft. The gear-wheels are always in mesh. The differential gear is mounted on the inner end of the second-motion shaft, and is not enclosed in the change-speed gear box; its casing is driven by the second-motion shaft. At each side of the differential is a sprocket, and a chain passes from each to the two halves of a live rear axle. The size of the differential and the strains imposed upon it are reduced by this arrangement (*see* also Fig. 724, p. 677).

The Oldsmobile transmission and change-speed gear is of the epicyclic type, and is out of the usual run, as shown by Fig. 730, p. 682. The low speeds are obtained by tightening a band brake around one member of the epicyclic gear, and a direct through-drive on the top speed is obtained by clutching the epicyclic mechanism. A chain drives the differential on the live rear axle. Perhaps the arrangement is made clearer by Fig. 420. In this A and B are the enclosed crank chamber, and C the motor crank shaft. This shaft has two epicyclic gears, which are brought into action by band brakes D and E, which hold the normally rotating drums containing internal racks. The right-hand one D gives the low speed, and the left-hand one E gives reverse motion. By means of a clutch on the shaft, these revolve as one when required and give the highest speed. The clutch is operated by a bell-crank lever F, which causes the sliding sleeve G to force four bell-crank levers against the arms H, carrying friction pads G, against the drum K. These three speeds are obtained consecutively by a hand lever L, which rotates the shaft M about its axis. The

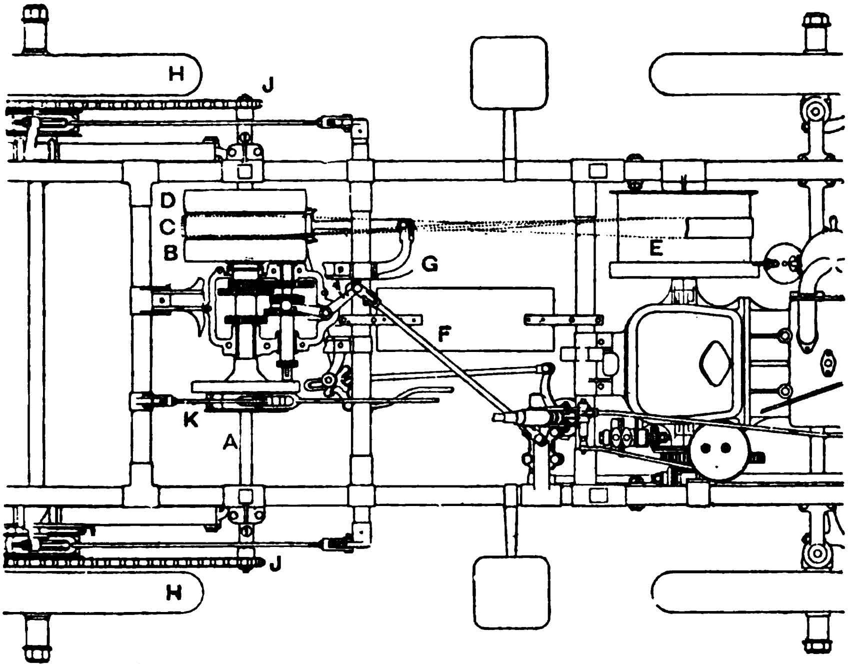


Fig. 421.—Delahaye Transmission and Change-speed Gear.

shaft operates the clutch and the band brakes by cams, the connection of the two of these with their band brakes being through telescopic fittings N, the cams tightening the two sides of the band brakes in this manner. The driving chain connects a centrally placed sprocket, with a corresponding wheel on the live rear axle differential gear. The additional brake drum O is rigid with the driving portion of the two epicyclic gears and with the chain sprocket, and is fitted with a band brake operated by the pedal P, through rod Q. The rectangular frame R is rigid with the triangular supports S, which carry the gear-operating shaft M; it is secured to four leaf springs, which pass from each side of it, at front and at rear, to the two axles. In Fig. 420 T shows the motor fly-wheel mounted on shaft C.

The transmission of the Hagen petrol lurry consists of a link motion, which imparts a varying motion to rods which drive the differential on the live rear axle through reciprocating clutches acting alternately, one driving whilst the other runs free. Link mechanism, operated by a hand wheel from the driver's seat, varies the gear ratio by adjusting the throw given to the driving rods. This gives a smooth progressive change of speed from minimum to maximum, and is a suitable arrangement for heavy lurries.

Delahaye cars with horizontal motors employ a system of transmission in which both belts and toothed gear are used. As shown in Fig. 421, the gear is grouped on the differential shaft A, the three pulleys B, C and D being belt-driven from the driving drum E on the motor shaft. The middle pulley C runs free and serves for disengagement; the outer one D is keyed on the differential, and at top speed gives a direct through-drive from motor to road wheels; the inside pulley B also drives the differential and is a part of the change-speed gear. There are the usual sliding gear wheels for forward and reverse motion, operated by rod F and crank G. The differential shaft drives the road-wheels H by chains, J. K is the usual band brake.

The Pick transmission is another example of mixed belt and toothed gear. Outside the motor fly-wheel, which is close up to the crank chamber and on the same shaft, is placed a wide pulley drum, which belt-drives a countershaft carried behind the live rear axle. On this countershaft are fast and loose pulleys: also it carries spur-wheels which mesh with others on the differential casing.

Two forward speeds are obtained by jaw clutches, which render either of the pinions rigid with the countershaft; for reverse motion, a sprocket wheel is clutched in the same way to the countershaft, a chain passing from it to the differential. On some Pick cars a Panhard type gear is used.

The Primus transmission is a third example of the combination of belts and gear wheels. The crank shaft lies across the car, and carries fast and loose pulleys, from which a belt drives the first-motion shaft of the change-speed gear. Upon the first-motion shaft are mounted spur wheels, and these can mesh with others mounted upon sleeves rigid with the shell of the differential, which is inside the gear box; through these sleeves pass the two halves of the countershaft, from the ends of which there is the usual chain drive to the rear wheels. The change-speed gear is of the ordinary sliding-wheel type.

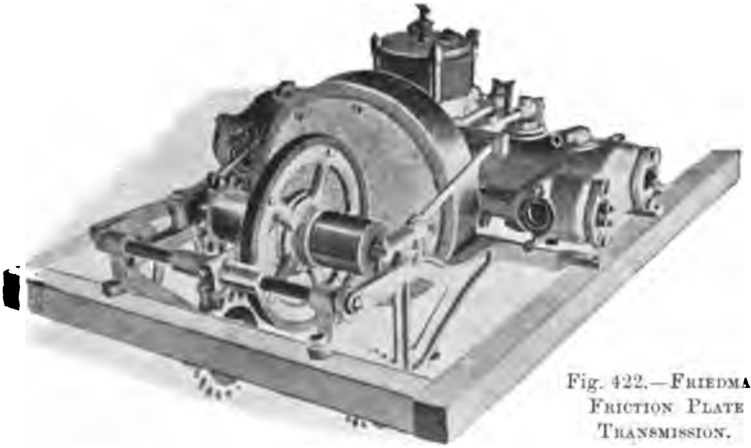


Fig. 422.—Friedman Friction Plate Transmission.

A leather belt with canvas core running on fast and loose pulleys transmits motion from the crank shaft to the first-motion shaft in the Belle (Swiss) cars. The rest of the gearing is of the Panhard type, with side chains driven by a countershaft.

In the friction plate system, either the main shaft or the fly wheel carries, or in any case moves, a plate against which presses a roller entraining the intermediary shaft in its motion. When at one side of the plate, the roller can glide along the shaft and give a forward movement; when it reaches the centre, movement ceases; and there is backward motion when it passes to the other side. The system is simple and adapts itself to slight changes of speed, but it has a great inconvenience; to avoid the roller skidding on the plate and causing considerable loss of transmitted power, the adherence, which is especially weak near the centre, may be increased by pressing the roller hard against the plate; but this pressure absorbs power and causes wear owing to the thrust produced between the plate shaft and one of the bearings, by the resistance presented to the rotation of the plate; in spite of this, Lepape and Ringelmann think highly of the system.

The objections to friction plate transmissions are (1) low mechanical efficiency, this varying with the pressure existing between the friction wheel and the fly-wheel; the pressure generally depends on the force exerted by the driver on his hand lever; (2) the lessened efficiency at low speed, just when the greatest power is required. Against these may be set the undoubted smooth running and the progressiveness and ease of speed changing.

Variable speed friction drives are features of the Friedman and of the Maurer-Union petrol cars. Briefly stated, the motor fly-wheel is smooth-faced, and the smooth periphery of a wheel mounted at right angles to it on a sliding sleeve is brought into contact with it. The relative speeds of the wheels will depend on their relative diameters and on the distance from the centre of the fly-wheel of the line of contact of the two wheels. The motion of the second wheel is transmitted to the road wheels in any suitable way (chains have the preference), and it will be understood easily that the nearer to the centre of the fly-wheel the friction wheel is approached, the slower will be the speed; when the friction wheel passes the centre of the fly-wheel, reverse motion is obtained. The Friedman motor and friction wheels are shown by Fig. 422. The fly-wheel is faced with copper, the friction wheel being mounted on the shaft parallel with the face of the fly-wheel. The friction wheel normally is not in contact; but it is put in contact by forcibly depressing a system of levers which acts on the sliding blocks containing the wheel bearings. The transmission from the friction wheel shaft is by sprocket wheel and chain to a countershaft, and thence by chain to the differential of the live rear axle. In the Maurer-Union car, an extra friction wheel, parallel with the motor fly-wheel, may or may not be employed: without the extra wheel, the system resembles the Friedman, except that the chain drive is from the left end of the friction wheel shaft to a sprocket on the left rear wheel only. The arrangement of the double friction drive is shown by Fig. 423. Friction discs A B (the former being a part of the motor fly-wheel) have between them the friction wheels C, D; C is the working wheel, D serving merely to increase the friction surface. The friction wheel shaft E has a sprocket on the left end, and the chain F drives a differential on the left end of the one piece axle G. By moving lever H the friction discs movable in the longitudinal axis of the car are brought into contact with the wheels C, D; and wheel C can be approached or removed from the centre of A by means of bevel gearing under the driver's control.

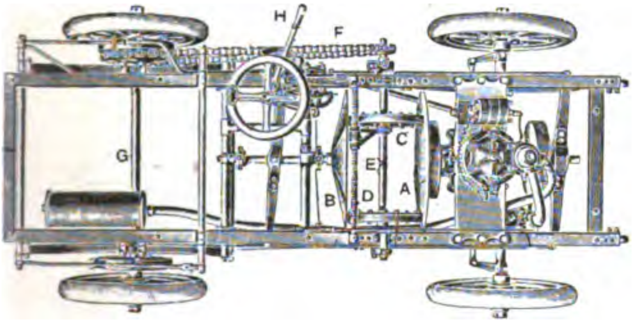


Fig. 423.—Maurer-Union Friction Plate Transmission.

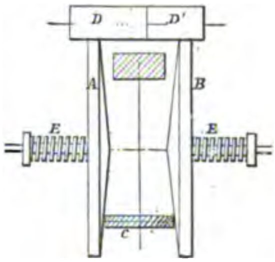


Fig. 424.—Ringelmann Friction Plate Transmission.

Friction plate transmission systems were employed on Tenting and Lepape cars. The crank shaft is furnished with a fly-wheel formed like a friction cone, driving two conical wheels placed in a line with the axis of the fly-wheel. Between these two wheels moves a large disc forming a friction plate constantly in contact with them; its shaft carries a pinion working by a chain, the differential being placed on the axle of the driving wheels. By moving the disc to right or left of the centre of the pinion, more or less far from it, backward and forward motion are obtained at different rates of speed. Similar transmission gear was employed in the American cars made by Bird.

Ringelmann estimates that the very ordinary results obtained by the friction plate systems is due to the pressure exerted on the roller being constant, whereas it ought to increase as it approaches the centre of the roller. His device to prevent this inconvenience is shown by Fig. 424, in which A and B are two friction plates given motion by the toothed gear D and D^1, of identical but inverse speeds; A B impart motion to roller C. The inner surfaces of the plates are flat instead of conical, and their inclination is combined with the power of the springs E so that the pressure between the roller C and the plates varies automatically, according to the required proportion, when the roller passes from the centre, where pressure should be maximum to the circumference, where it should be smallest.

The Fouillaron is the best known and most representative of those systems in which the power is transmitted by belts working over extensible pulleys, the speed varying according to the mechanically produced alteration of the ratio that the diameter of the driving pulley bears to that of the driven one. Many important details go to make up the Fouillaron system, but there is space here to deal only with the leading features. A diagrammatic plan is shown by Fig. 425, a view of the chain-belt that connects the two pulleys being given by Fig. 426. A and B are two extensible pulleys; that is, they are each formed of two opposite cones having slits or openings so that one can penetrate the other, as illustrated at B. The pulleys are so mounted on their shafts—A on the motor shaft and B on the differential shaft carrying the chain sprockets—that one cone of each pulley can be moved and the working diameter thus altered. In practice it is the driving pulley A that is altered by the driver, the other pulley being automatically changed in diameter so that the chain-belt remains equally stretched. Change of speed is operated by turning a small wheel, placed on a more or less vertical shaft just below the hand-steering wheel. By means of worm gearing the

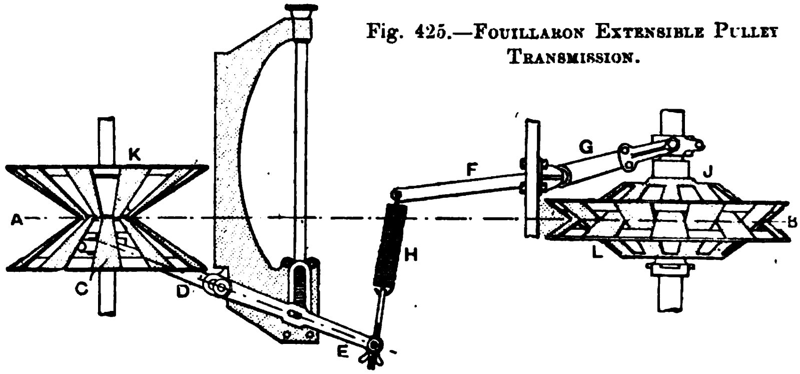


Fig. 425.—Fouillaron Extensible Pulley Transmission.

shaft moves laterally the lever arm of the loose cone C of the driving pulley A. By means of a system of levers, D, E, F and G, and by means of the very strong spring H, the motion of the driving pulley A is transmitted to the driven pulley B, and as the sliding cone C draws out or in to make the working diameter of A smaller or larger, the sliding cone J, of driven pulley B, draws in or out so as to make the working diameter of B correspondingly larger or smaller. K and L are the two fixed cones. In a car exhibited at the Paris Salon, 1902, the sympathetic movements of the two pulleys were obtained by the use of chains, not unlike cycle roller chains. It is easily understood that the larger the working diameter of the driving pulley in proportion to that of the driven one, the greater will be the speed of the car. The chain-belt is made up of pieces of leather (Fig. 427) threaded upon eight twisted gut strings, about 4·7 mm. (·1875 in.) in diameter; from eight to ten thicknesses of leather are riveted together to form a link, and slightly pared away or hammered so that at the bottom the link is not so thick as at the top; this is shown at B, Fig. 426. The links are so threaded that the strings, leaving the top row of holes in one link, enter the bottom row of holes in the next, and of course *vice versâ*. This suffices to separate the links ever so slightly. The advantages justly claimed for the Fouillaron system are smooth transmission of power, the absence of all toothed gearing, and an absolutely progressive change of speed without any of the shocks and strains that a change of speed always involves when toothed gearing is employed. For reverse motion, a device disconnects one of the sprocket wheels on the driven pulley shaft, and the car is driven by one of the side chains only, the differential serving as a device to alter the direction of the motion.

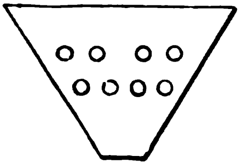


Fig. 427.

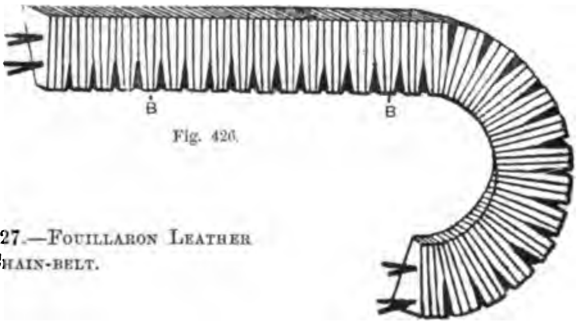


Fig. 426.

Figs. 426 and 427.—Fouillaron Leather Chain-belt.

The Dumaresq Simplex variable speed gear, now in process of development, also employs expanding pulleys, but on a different principle. The power is transmitted from one to the other by chain, and the effective diameters of the driving and driven pulleys vary inversely and simultaneously.

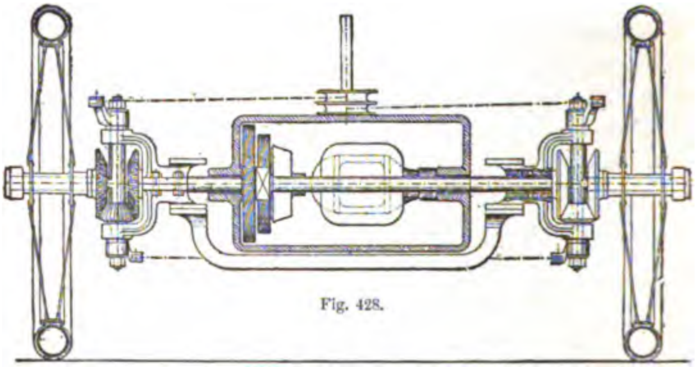


Fig. 428.

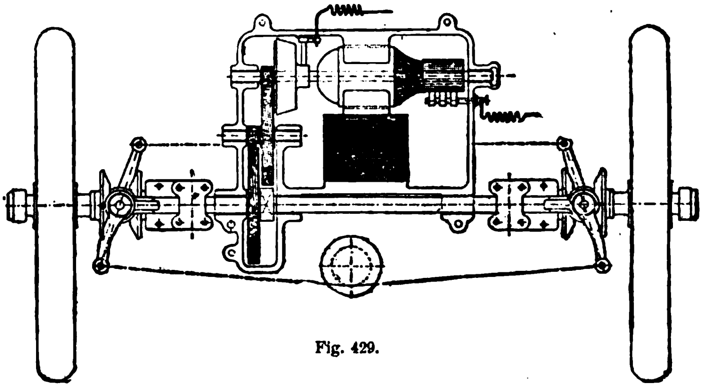


Fig. 429.

Figs. 428 and 429.—Jeantaud Electric Motor Fore-carriage Transmission.

In electric cars, backward motion and changes of speed can easily be obtained by aid of the electric motor, and consequently mechanical speed-changing gear is not much used.

Electric cars resist side-slip remarkably well, according to Colonel R. E. B. Crompton. This is partly due to the fact that the driving power can be applied to the front wheels, which undoubtedly constitutes one of the great advantages of electrical propulsion. Another advantage over petrol or steam-driven cars is that it is easy to apply separate power to each driving wheel of an electric car, so that there is no need for a differential gear. Up to the present, apparently, the majority of electric cars use tooth gearing, in spite of the fact that chains are easier than tooth gearing to lubricate and to maintain in silent running condition. The slight noise made by electric cars generally proceeds from the tooth gearing, whereas the absolutely silent automobiles, electric or steam, generally use chain transmission. Speed changing in electric cars is operated electrically by means of the controller, as described on pp. 333 to 339.

In some Jeantaud cars the motor drives the differential shaft by toothed gear, the differential driving the rear wheels by chains. In the three-quarter coupé, where the front wheels are both driving and steering (*see* Figs. 428 and 429), the armature shaft drives the differential shaft by means of spur wheels (there is no magnetic clutch on the left of the secondary coil); each of the two parts of the differential shaft has at its end a bevel pinion gearing with a pinion whose vertical axle is the wheel pivot. This other gears in turn with a pinion on the axle of the driving wheel. Thus the wheels can turn any way without ceasing to receive motion.

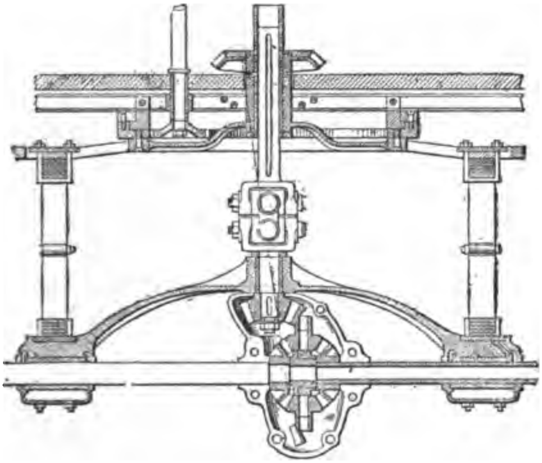


Fig. 430.—Doré Steering Motor Fore-carriage.

Doré cars have a fore-carriage used both for driving and steering (*see* Fig. 430). The dynamo is on the seat at the driver's feet. To transmit its motion to the wheels in spite of the bending of the springs (which causes the distance from axle to motor to vary), a motor drives a hollow vertical cylinder (forming the pivot on which all the fore-carriage turns), inside which a rod in two parts can ascend and descend, the two parts being united by a double universal joint. The lower part carries a bevel pinion which entrains the wheel of the differential; the wheels are keyed on the two parts of the axle. A key forces the rod to follow the motion of the rotating cylinder. This fore-carriage can be employed with a petrol motor also.

Patin cars employed a transmission system shown by Figs. 431 and 432. The motor A is fixed direct on the axle B, curved in at the centre and widening out to a given point in an oval shape to allow the differential and its wheel to pass to the axis of its horizontal secondary coil; the pulley C is covered with leather. Under the action of lever D, and in the plane of pulley C, moves vertically the triangular sector E, carrying pulleys F G, of unequal diameter, but both larger than that of the pulley C. When one or other of the pulleys F G is brought into contact with the latter it begins to move, driving its shaft and with it a toothed pinion, which forms one with it and constantly gears with the toothed wheel H of the differential. The pinion of the latter drives the two parts J, which pass inside the axle journals without any friction. By aid of the extreme nuts the clutch couplings K entrain the hubs L of the wheels. It suffices to change the pulley in contact with C to make a change from full speed without fear of shocks and snapping of teeth as with toothed gearing. Disengaging is operated by breaking all contact between the pulleys C on the one hand and F G on the other: for engagement contact is restored.

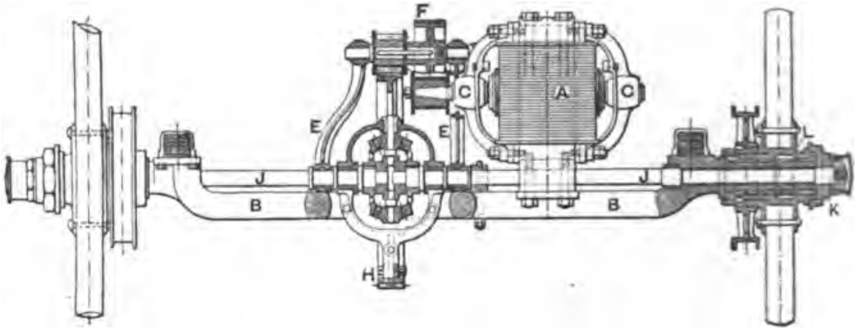


Fig. 431.—Patin Electric Car Transmission.

The Mildé-Mondos transmission had an electric differential in place of the mechanical differential (*see* Figs. 433 and 434); *a* and a^1 are the two secondary circuit rings of the motor, each comprising a special winding; one, *a*, is keyed on the solid shaft *b*; the other, a^1, on the hollow shaft b^1, concentric with the first, of which, moreover,

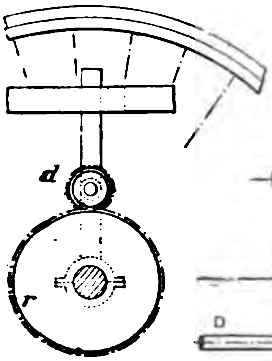
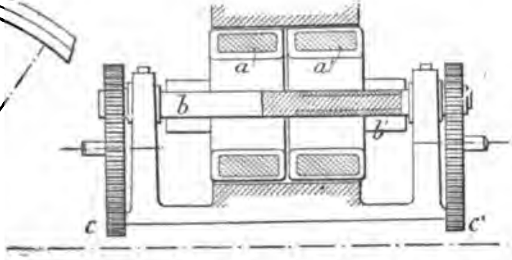


Fig. 433



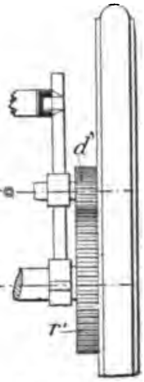


Fig. 434.

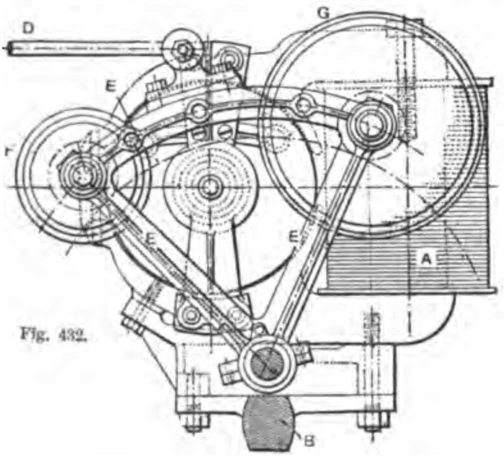


Fig. 432.

Fig. 432.—Patin Clutch. Figs. 433 and 434.—End Elevation and Section of Mildé-Mondos Transmission Gear.

it only surrounds part of the length. At the end of each shaft a pinion gears with the wheels *c* and c^1, which, by means of a flexible transmission or other device, in turn drive pinions *d*, d^1, which gear with the toothed wheels *r*, r^1, fixed on the car driving wheels. Thus these wheels can displace themselves as regards each other because the secondary coils can acquire different rates of speed, the motor action becoming more powerful in the ring corresponding to the wheel receiving the maximum strain.

CHAPTER XII.

AXLES AND STEERING GEAR OF AUTOMOBILES.

AUTOMOBILE driving axles and steering axles are distinguished between as follows: they are driving when the two driving wheels are keyed on them or on their two parts united by the differential, or when they are loose with the chain wheels; whilst steering axles carry the steering wheels. In a general way the rear axle is driving and the fore axle steering. The other position, however, was to be found in the Weidknecht omnibus, the car of the Compagnie Générale des Automobiles, and the Moriss voiturette, and the steering axle in the rear in fact gives smoothness and stability when rounding sharp curves, but it is said to cause difficulty in starting, the car being stopped sometimes by contact with a curb-stone. Some axles are both driving and steering, in which case they are always at the front. The Lohner-Porsche petrol-electric car has such an axle.

Skidding, sometimes caused by having the steering driving axle in front, is a great inconvenience, for it may extend to a head-to-tail motion; according to Forestier it occurs when the wheels of the fore-carriage meet with a resistance which slackens motion and the rear wheels are on any part of a road where friction is too slight to prevent side-slipping. To prevent this inconvenience, Forestier recommends the loading of the fore-carriage so that the kinetic energy of the wheels can overcome the resistance they meet with without decreasing the speed much more than that of the rear wheels. If the fore-carriage is loaded the wheels must be increased in diameter, and it is a question whether they should be left steering in such a case. However, it is not always resistance as above that makes the car swing round, for it may happen that one of the road wheels does not travel over the same distance as the other, the car then turning to the side on which the wheel runs the shorter distance. This happens particularly when one wheel is on a part of the road, such as a tram rail, pavement or slippery asphalt, where adherence is small; or skidding may be caused by the brakes of the two wheels working unequally. In such circumstances swinging round cannot be prevented by increasing the load on the fore-carriage; then the remedy is to make the wheels turn together by stopping the action of the differential.

Whether the fore axle be steering or driving it is desirable for it to have the same width (really length) as the rear axle, so that the driver may be able to judge whether the available space is sufficient for the vehicle; and the car gains in stability. Great solidity and strength are required for automobile axles, as they have to support both the body and the mechanism, a greater general weight than that of a horse-drawn car, and they are subjected to jolts which are aggravated by the more or less great speed. Consequently the axles must be made of the best metal. Steel tends to become brittle under the influence of vibration; and only soft steel can be used. Wolseley axles are of Vickers' special axle steel, and the use of weldless steel tube axles and those forged and bored from end to end is increasing. For iron axles the metal is selected soft and fibrous, giving an elongation as far as possible of 26 to 27 per cent. under a rupture strain of from 35 kg. to 36 kg. per mm.^{2} (22·21 tons to 22·84 tons per square inch) of section.

Nickel steel has proved a satisfactory material for the axles of Duryea cars.

The axle may be straight or cranked, with or without shoes or washers welded or hammered into the metal. Straight axles without shoes are made in one piece, rolled or forged with the stamp hammer. On the contrary, straight axles with shoes are generally made in two parts which are welded together. The shoes may be welded on, but heavy axles with shoes should be made in one piece. Crank axles without shoes usually are centered in drawing; a sufficient boss must be left so that after bending the crank will have the same section as the rest of the axle. Crank axles with shoes must be forged in one piece; this is desirable for washers also, but welding can be adopted providing it is well done. The journals are stamped as near as possible to their finished dimensions to avoid much subsequent shaping, they are case-hardened for a thickness of at least 0·2 mm. (·007 in.) and then the journal fillets are annealed to remove brittleness. Finally, the journals are adjusted so that in use they will neither wear away nor be deformed much. In horse-drawn vehicles the journals are inclined downwards, so that in spite of the dish of the wheel the spokes will be perpendicular to the ground and thus loaded vertically. In automobiles the motor wheels form one with the toothed wheels, which turn in the vertical planes of the endless chains which drive them and the journal axles cannot be "set" much except certain rarely employed devices are adopted. But this does not apply to the journals of steering axles, which sometimes, however, are not "set," nor are the wheels they carry perceptibly dished.

The axle boxes contain balls or rollers and grease or oil. Grease boxes are employed only for heavy vehicles. Patent oil axle boxes are made in about the same shape as that adopted by the inventor, J. Collinge, in 1787. Lemoine, however, suppresses the groove in the top part of the journal, this allowing of better grinding. They are made of bronze, or more often of forged iron case-hardened, but never of cast iron, which would be too brittle. Bronze gives more friction and lessens the risk of skidding, but it wears away more quickly than iron, and this wear causes a noise when the wheel turns. The rings and nuts generally are made of bronze for the sake of cheapness. For heavy vehicles one iron nut with notches perhaps is better. The half patent axle without ring or nuts, the box being joined to the wheel by washers and bolts, gives greater security, because the nut does not become loose, and if the journal breaks the wheel is retained, but it cannot easily be removed. These axles must be kept perfectly clean and lubricated with sheep's-foot oil, or ox-foot oil, or cheap mineral oils. Great inconveniences are caused by want of oil or the detachment of a fragment of broken metal from the box, the wheels skidding, the journal wedging, and even the journal adhering to the box through overheating. Normally a well lubricated wheel should run from 800 km. to 1,000 km. (roughly from 500 to 620 miles) without requiring any attention. Ball bearings, according to G. Richard, reduce the journal friction by 90 per cent. Balls 10 mm. (0·39 in.) in diameter, well made of hard steel or soft Bessemer steel with 0·1 per cent. of carbon, well tempered and polished, have a crushing resistance of 26 kg. per mm.^{2} (16·5 tons per square inch), and can support, without losing their roundness, between plane surfaces of Bessemer hardened steel as much as 1,100 kg. (2,220 lb.) per ball. This resistance can be increased by having several rows of balls or cylindric rollers. Forestier says that the coefficient of friction of the journals may be taken as equal to 10 kg. (22 lb.) per tonne with patent axle boxes, 5 kg. (11 lb.) with ball bearings, and 2·5 kg. (5·5 lb.) if smaller balls are placed between those supporting the axle so as to prevent all gliding friction amongst the larger ones. In the United States comparison has been made of the strains needed for the traction of two similar wagons (1) with a roller box and (2) with a lubricating box; the proportion of (1) to (2) was:—

Load of	3,300 kg. (6,660 lb.)	... ...	1 to 2·90
Do.	8,300 kg. (18,260 lb.)	... ...	1 to 3·67
Do.	10,000 kg. (22,000 lb.)	... ...	1 to 3·98

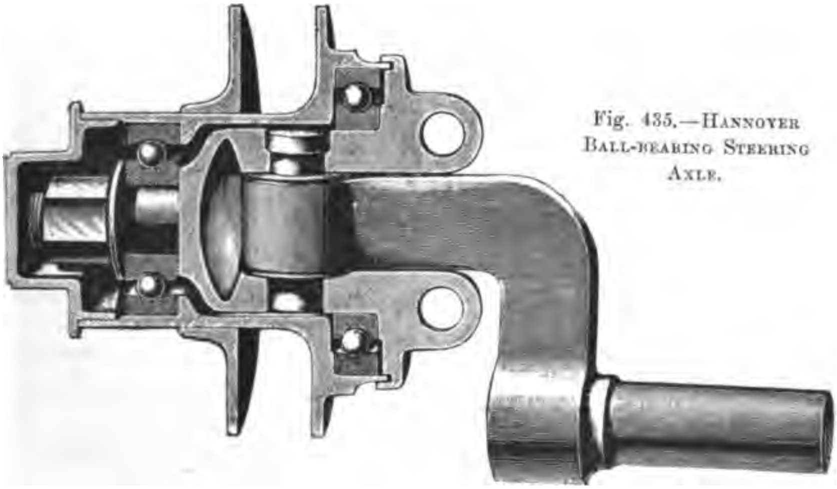
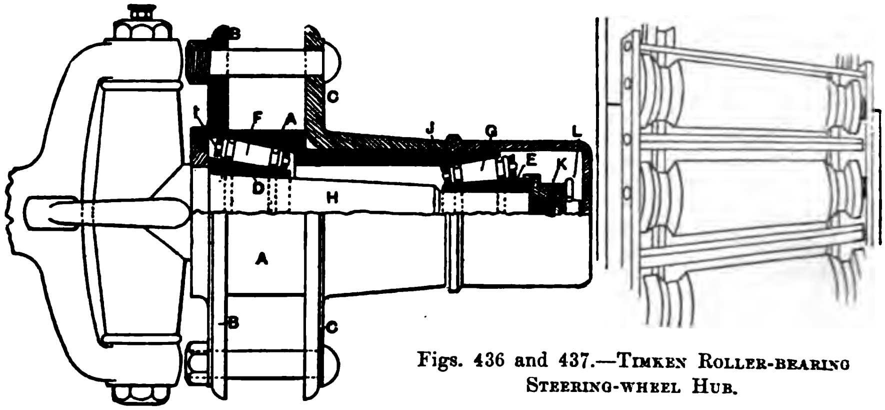


Fig. 435.—Hannover Ball-bearing Steering Axle.

Experiments made with an entire train on the Western Railway of France demonstrated that rollers give much less resistance to rolling than do ordinary boxes, the resistance to starting being diminished by from 35 to 40 per cent. In automobiles it would be particularly advantageous to reduce the resistance to starting due chiefly to the want of oil between the journals and the boxes; for when lubrication is copious the coefficient of friction increases as the square of the speed. Forestier suggests that the lubricating system much in vogue on railways be imitated in this—a wick deposits on the journal just enough lubricant to prevent wedging; this latter inconvenience is to be feared more with automobiles than with railway waggons. Already there is a number of ball-bearing axles. There are the Belvalette and Vermot axles with two rows of balls, one on each side of the journal; the Hannoyer with four rows; Simonds with eight rows; and Gondefer, Gros and Picard axles with ball or roller bearings, in which the chief balls or rollers are kept separate by a second ring of balls or rollers lodged in special grooves, this device preventing all gliding.

The Hannoyer new steering ball-bearing axle is shown by Fig. 435. It has a nickel steel body, with or without shoes, and straight or curved. A steel hub is mounted on a nickel steel journal and fixed there by a screw cap, and there are two ball bearings, as shown. Adjustment and detachment are easy with such an axle as this.



Figs. 436 and 437.—Timken Roller-bearing Steering-wheel Hub.

Most automobile constructors consider that the patent axle wears very well, and they say that the ball system is more expensive, not so solid, and more complicated than useful, the breakage of a single ball causing the journal to wedge, and mere wear causing bad work; the friction of the journal, they consider, is only a small item in the total resistance to rolling.

The Timken roller-bearing steering-wheel hub (Fig. 436) makes possible the adjustment of the bearing even when the races or containing collars are worn. Fig. 437 shows more clearly the shape of the rollers and the method of placing them. In Fig. 436, the steering axle H is machined from the solid bar, case-hardened and ground, and on its inner end is fast fitted the roller race D; the race

E for the outer set of rollers forms a tight sliding fit over the outer end. The cases enclosing the rollers F are formed by the coned portions A of the axle box. The inner flange B and the outer flange C form the nave of the wheel for the reception of the spokes, and are stamped from steel plate; B is brazed to the axle box A, and C forms a tight fit over the reduced outer diameter of the same, being also bolted to the inner flange as illustrated. These stamped flanges give strength and lightness. A dust cap screws on the end of the axle box, which is made grit-proof and oil-retaining by a closing ring carrying a felt washer. The tapered rollers F and G are kept in their relative positions by ring cages, I and J. The pivot pins in the ends of the rollers rotate in holes drilled in the rings which are carried round with the rollers. To adjust for wear, the nut K is screwed up against the outer adjusting bearing cone E, and any slack is taken up equally by the two sets of rollers; for further adjustment a thin washer can be inserted between K and E. The adjusting nut is locked by the cotter pin L.

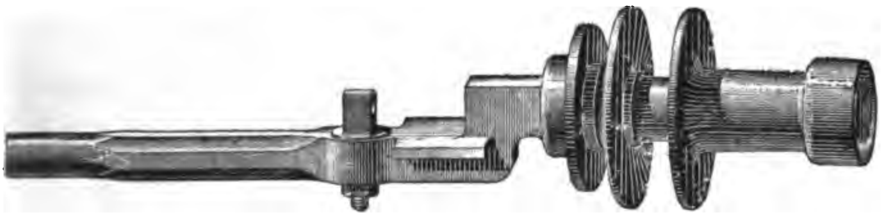


Fig. 438.—Lemoine Patent Oil Axle.

Driving axles are made variously; their naves may or may not carry the band brake pulley and the sprocket wheel which is driven by the endless chain. Figs. 438 and 439 illustrate two types constructed by Lemoine. Fig. 438 is a general view of a patent oil driving axle, depressed and having an eye to receive the fastening of the connecting rod; the illustration shows a washer beaten out of the metal mounted with a metal nave and hoop sleeve carrying a disc to fix the toothed wheel. Practically the same axle is shown by Fig. 439, but on this is fixed a brake pulley and sprocket or chain-wheel.

Fig. 440 shows the Darracq rear driving axle, A being the differential shaft, B and C the left hand and right casings respectively, D the differential gear box, E the brake with band passed twice round the differential box, F the wheel driven by the pinion *f* on a shaft which has a flexible joint at H, J the spring attachment piece, K the naves of the back wheels, and L ball bearings.

The de Dion-Bouton car driving axle is illustrated in part by Fig. 441, which shows the nave, cap, axle sleeve, T, brake drum, V, etc. This and the Darracq axle (Fig. 440) are types of driving axles.

The two-pivot broken steering axle is a source of danger, especially at full speed, on account of its want of precision. The bicycle mounting, which was that of the Cugnot trolley, would have given the simplest solution; but it would have been unsafe, as it would have reduced the supporting polygon to a triangle. The ordinary fore-carriage with pivot would have caused the same difficulty as the single steering wheel in turnings of 90°. In an automobile the fore-carriage gives a defect which, owing to the pole or shafts, is not present in horse-drawn vehicles; any obstacle met with by a wheel tends to make it turn with great force around the pivot, and in order to keep the car in a straight line the great strain has to be counterbalanced. This could not be done easily by means of a lever directly connected with the axle; this lever usually is difficult to handle, but under such circumstances might be snatched from the driver's hands. An endless screw and irreversible transmission might have been employed, and a few builders—Pouchain,

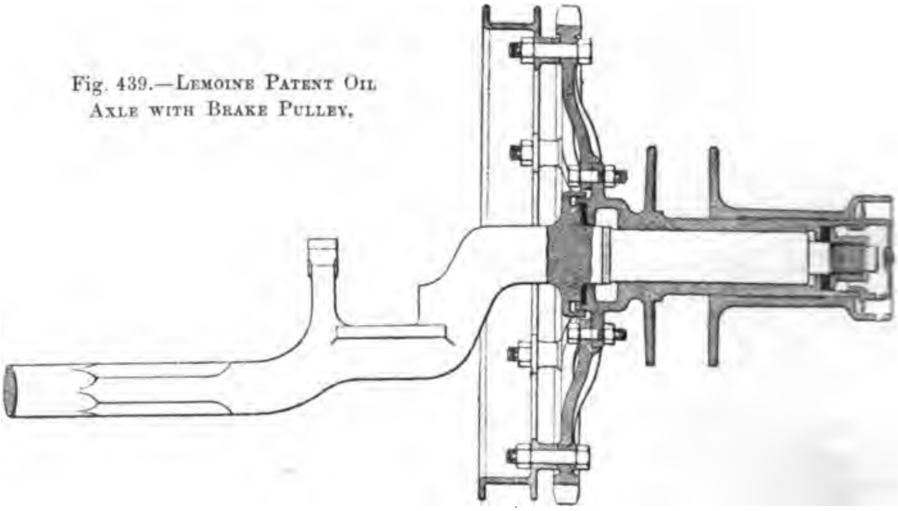


Fig. 439.—Lemoine Patent Oil Axle with Brake Pulley.

Le Blant, and Doré—have adopted this system, which, however, exposes the steering parts to strains which might cause dislocation. The remedy is to immobilise the steering axle to the driving axle parallel to one another, and to make each wheel movable around a pivot quite close to the end of the axle. Thus in the Duryea car the prolonged axis of the pivot intersects the ground at the point where the wheel is in contact. Sometimes, instead of being completely immobilised, the steering axle remains free to move around a perpendicular pivot, but it always remains in a vertical plane parallel to that of the driving axle, and the supporting polygon is not altered. The two-pivot fore-carriage was invented by Lenkensperger and patented by Rudolph Ackermann, of London,

Fig. 440.—Darracq Rear Driving Axle.

Fig. 441.—De Dion-Bouton Rear Driving Axle.

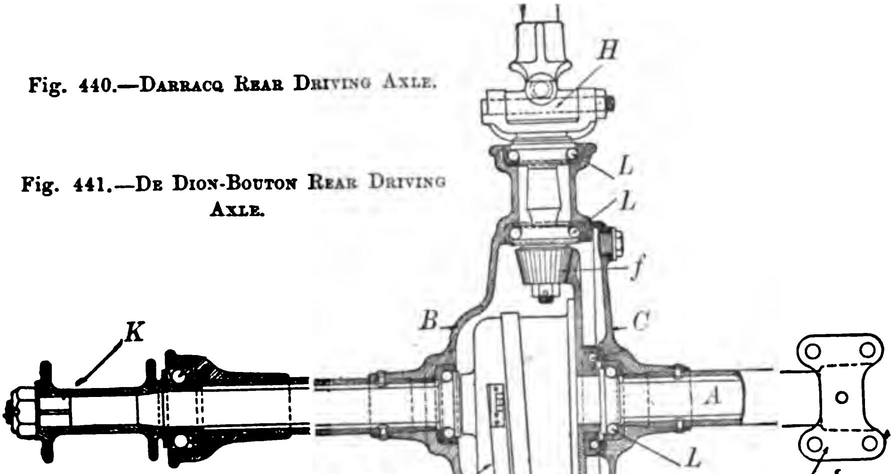


Fig 440.

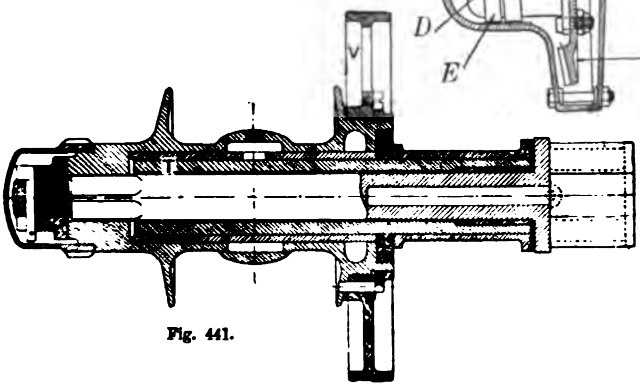


Fig. 441.

in 1818. Originally, it exposed the wheels to skidding along the ground because the axle of the journals of the steering wheels did not converge, in turning, at a single point, and then the four wheels had not a common axis of rotation. The Bollée steam car *Obéissante* in 1873 had the two-pivot system with cams intended to make the prolongations of the journals meet in precisely the same point of the vertical plane of the rear axle.

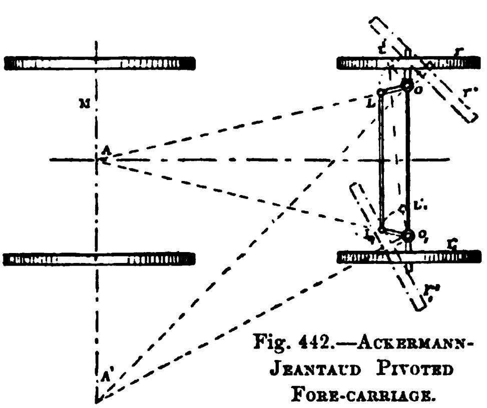


Fig. 442.—Ackermann-Jeantaud Pivoted Fore-carriage.

In 1878 Jeantaud invented a modification of the Ackermann device which enables easy turning of the car, because in horizontal projection the axis of the journals always meet on the prolongation (or at least very near it) of the rear axle axis. In Fig. 442, which shows the principle of the Ackermann-Jeantaud steering gear, *r r* are the horizontal projections of the steering wheels, *o o* being those of their respective pivots. By joining these two latter points with the intersection A of the median axis of the car and the rear axle axis M, an isosceles triangle is formed, the sides of which are taken as the direction of the connecting rods O L, O^1 L^1, which invariably are united with the journals of the two wheels. These two rods finally are hinged with the cross piece L L, which transmits to them in an interdependent manner the motions of the steering bar or, better, the fly wheel; when, in order to turn, wheel r is brought into the position r^1 so that the verticals O A^1 and O^1 A^1 on the wheel planes intersect each other in a point A^1 situated very approximately on the prolongation of the axis of the rear axle. The locus of the points A^1 strictly is a curve to which line A A^1 is a tangent with which it may be practically confounded. The cross-piece L L^1 can be brought more or less close to this axle, but the nearer it is the greater will be the field of action of the wheels, without it being possible, owing to the limited amplitude of the arcs described by the connection rods, to make the car pivot on one of the rear wheels. The Jeantaud device now is employed almost exclusively, though it gives good results only for angles of not more than 30°. Consequently, the system is not perfect yet. With a view to elucidate the matter, Bourlet made a very interesting study which here is epitomised. He distinguished (1) the system of joining the two wheels from (2) the transmission gear.

As regards the system of joining wheels, connecting rods are the easiest to make and the least liable to become loose. As to whether it is possible with them to realise the essential condition that in turning

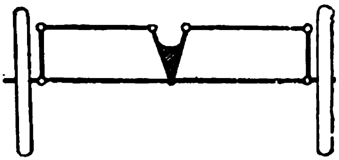


Fig. 443.

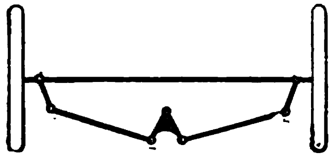


Fig. 444.

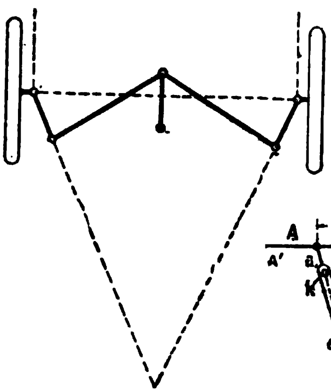


Fig. 445.

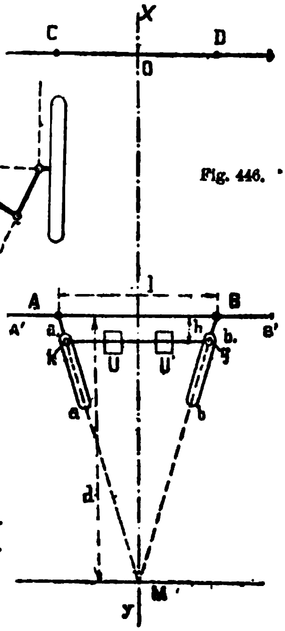


Fig. 446.

Fig. 443.—Jenatzy Double Quadrilateral Steering Gear.
Fig. 444.—Bollée Double Quadrilateral Steering Gear.
Fig. 445.—Lavenir Concave Pentagon Steering Gear.
Fig. 446.—Bourlet Steering Gear.

no wheel skids laterally, that is, in every position of the system, the four wheels turn around an instantaneous axis of rotation situated in the vertical plane of the rear axle, theoretically it is possible, but practically it is not; any system giving this condition would involve too great a number of connection rods—there would be at least eighteen according to the devices hitherto proposed. But if a mathematically accurate solution is not practicable, something near the mark can be attempted, because it suffices to assure a maximum turning angle of 40° for the car. In fact, cars with driving wheels in the rear do not turn when the wheels are fixed at more than 45°. Thus the fore wheels, under the influence of pressure, from the first tend to skid, and do so if the fore-carriage does not break. Bourlet ascribes this impossibility of turning in small radii to the defective steering gear actually employed when fixed at great angles and to the differential ceasing to work.

Connecting rod couplings are distinguished from each other by the shape of the polygons they form; there are (*a*) simple quadrilateral, (*b*) double quadrilateral, and (*c*) concave pentagon.

The quadrilateral coupling may be inside the axles, as for the Ackermann-Jeantaud device, Fig. 442, or outside the axles, as in the Panhard and Levassor. The Ackermann-Jeantaud device, as has been said, gives suitable steering only when the gear is fixed at an angle of 30°—beyond this it is really bad; and as a rule, in the case of interior quadrilaterals, any inaccuracy rapidly grows. The exterior quadrilateral is preferable, because with the same frame it gives a greater maximum steering angle, and because whilst the jolts caused by the road on the steering wheels cause pressure on the rod L L, Fig. 442, in the interior quadrilateral they cause traction in the exterior quadrilateral, and this is more desirable. Bourlet endeavoured to find out the best possible system of hinged quadrilaterals, and his result can be realised only with a long narrow car, for if the car is short and wide the maximum steering angle is too small. Therefore the single quadrilateral systems must be abandoned.

With regard to connecting rod couplings having a double quadrilateral, by dividing the single quadrilateral into two, the width of the car is, as it were, decreased one half and matters improved. To practically obtain this the rods near the two quadrilaterals must be connected one with the other so as to form a sector turning around the middle of the steering axle. This is the arrangement in nearly all the actual rod systems, particularly the Roger, Lepape, and Jenatzy, in which the quadrilaterals are two rectangular trapezes. Fig. 443 shows the Jenatzy steering gear with double quadrilateral (rotary axis of sector on axle). In the Benz and Bollée systems with double equilateral (Fig. 444) the rotary axis of the sector is not on the steering axle; a variable parameter is taken. In fact, there are more parameters than needed, and Bourlet demonstrates that an almost perfect connection can be formed in which the sector is replaced by a single rod. Following this up, Lavenir invented a system with concave pentagon (Fig. 445), which is indisputably the most accurate of all the systems hitherto invented; it is strictly accurate from 0° to 60°, and at 90° the error is only about 3°.

It is fairly obvious that a cam connection can be made giving any required relation between the steering gear of the wheels, and, indeed, several devices of this kind have been invented, for instance, that of Sydenham and Walkinson; all have the inconvenience of very rapidly becoming loose. Bourlet invented a slide mechanism which makes the steering wheel journals converge precisely in any position towards the same point of the rear axle. It is based on the fact, geometrically demonstrated by the inventor, that if the two journals A^1 a and B^1 b, Fig. 446, are connected with two arms a a^1 and b b^1, that intersect in the point M vertical to A^1 B^1, and symmetric with O the middle of the rear axle C D with regard to fore axle A B, the point M describes a straight line parallel to A^1 B^1 and that inversely if this point M describes the straight line E F the aforementioned condition of convergence is fulfilled. The problem then is reduced to this: unite the two arms a a^1, b b^1 by such a mechanism that M will describe the straight line E F. For this Bourlet furnishes the two arms with two slides a a^1 b b^1 (Fig. 447) in which run two rollers placed at the end of a rod g k which slides in two sleeves U U^1. which maintain it at a constant distance h from A B (*see* Fig. 446).

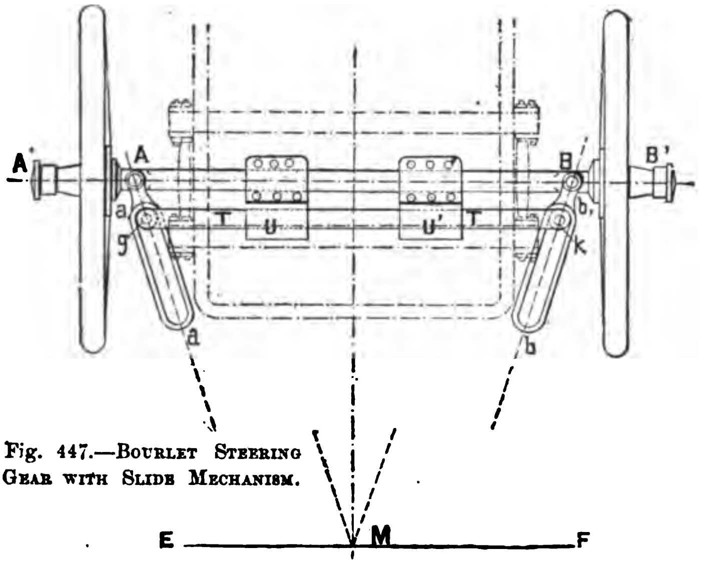


Fig. 447.—Bourlet Steering Gear with Slide Mechanism.

Point M thus describes the straight line E F, for the two triangles M A B and M g k remain similar and in constant proportion, which is that of their bases A B and g k; d is the height of the triangle M A B, that of triangle M g k is d – h. Owing to the similitude of the triangles $\frac{d}{d-h} = \frac{A\,B}{g\,k}$ = constant, and as h is constant so is d also.

The Bourlet system of steering is effected as in Fig. 447. It is possible to act on rod T by any of the steering mechanism to be described later. This system of joining is almost as simple as the Ackermann jointed quadrilateral, over which it has a marked superiority. The jolting of the wheels in rough roads makes rod T, Fig. 447, work in traction as in the Panhard and Levassor steering gear; but in addition to the theoretical superiority of strict accuracy, the Bourlet gear has the advantage over the last named of not having diverging arms A a^1 and B b^1 which necessitate inconvenient lengthening of the journals as soon as the road becomes wide comparatively with the width between the wheels. Davis, an Englishman, constructed a device differing from Bourlet's only in the style of workmanship; the two arms A a^1 B b^1, instead of being furnished with slides, are solid and run in cylinders hinged on the ends of rod g k. The other letters in Fig. 447 have the same references as in Fig. 446.

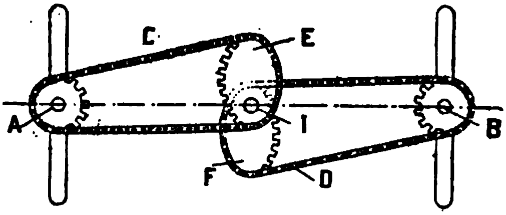
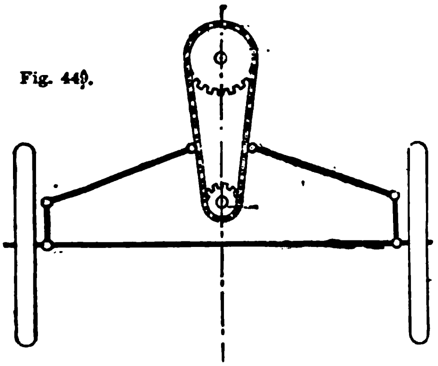


Fig. 448.—Bollée Chain Steering Gear (Old System).

Chain and toothed gear connections have been abandoned because they quickly grow loose. The Bollée old steering gear (Fig. 448) had chains; the two steering wheels were each placed in a vertical fork like the steering wheel of a tricycle. At their top part the axes A and B of these forks had pinions connected by chains C and D to two elliptic interdependent eccentric pinions, E and F, turning around an axis, I, placed in the centre of line A B. Theoretically, the choice of the shape of the pinions E and F gives exact connection, but practically the variability of the tension of the chains C and D gives a very refractory steerage system. The Delahaye gear (Fig. 449), sometimes also employed by Peugeot, is a combination of chains and connecting rods. With it also the flexibility of the chain gives considerable play, which makes this system one of the least recommendable. The Priestman and Wright steering gear, shown by Fig. 450, is a toothed system. In this, the steering handle is mounted at the top end of a vertical shaft whose lower end carries a pinion gearing with a toothed sector. The sector carries the vertical shaft G, upon which the double sector H is keyed eccentrically. The two parts of this double sector gear with other eccentric sectors with arms cast on and hinged to connecting rods K, which are hinged to levers fixed to forks M of wheels N. The form and eccentricity of the sectors G and H are calculated to transmit to the wheels differential motions suitable for good steerage.

Fig. 449.



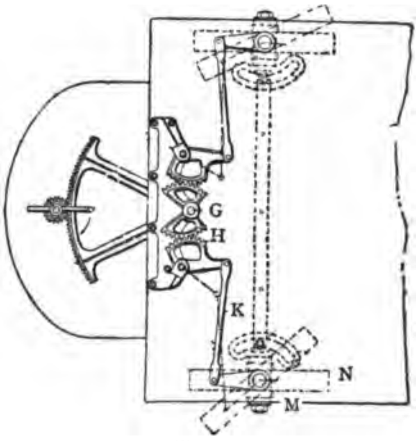


Fig. 450.

Fig. 449.—Delahaye Chain Steering Gear.
Fig. 450.—Priestman and Wright Steering Gear.

The transmission mechanism of the wheel connection system, and consequently of the wheels themselves, must have the least possible play, be easily handled, and at the same time act promptly, and be flexible enough to follow the relative displacements of the body and fore-carriage (the driving shaft, with its lever steering bar or hand wheel, is fixed to the body, and the system of the wheel connections is only connected with the latter by springs). The inclined hand wheel at present is the most popular controlling part, the lever being abandoned, as it is suitable only for slow cars, such as electrically driven ones.

The bell crank steering gear is the simplest, and consists of merely hinged rods, the arrangement of which can be much varied. As somewhat frequently employed, one of the arms, as O L (Fig. 442, p. 436), is prolonged so as to form the bell tie-rod, which the controlling shaft works by a lever arm and a tie-rod. There is a double hinge with vertical and horizontal axes on each end of the tie-rod to enable the mechanism to follow the relative displacement of the body of the car and the axle. In the Panhard and Levassor adaptation the bell tie-rod, instead of being moved by a lever arm, is worked by a toothed sector; at the lower part of the fly-wheel shaft a worm or pinion gears with a toothed sector situated in a vertical plane. This sector has a lever arm which draws or pushes the bell crank rod *a*, Figs. 451 to 453.

Jeantaud employs to move the tie-rod a rack which prolongs the same and which gears with the pinion placed at the lower part of the controlling shaft; the tie-rod itself is hinged in a point of the connecting rod L L, Fig. 442, p. 436.

With regard to chain and toothed gear transmission, the firms which have adopted the double quadrilateral transmission frequently simply employ chains. The sector E I F, Fig. 454, has a concentric pinion, Q, united by an endless chain, C, with the pinion P keyed to the lower part of the driving shaft O. Usually, pinion P is smaller than Q so as to obtain a demultiplication, which makes the steering gear work more smoothly, with greater sensitiveness, and more slowly.

Irreversible steering gear is necessary. The mechanisms just described (except the Panhard worm gearing) have a defect which is very tiresome for the driver, who cannot release the steering gear without the car running into the side of the road. These systems may suffice for ordinary speeds, but with those which seem likely to be adopted and are already employed in races the driver has not time to remedy the swerving of the car caused by jolts. It is prudent to arrange the mechanism so that the obstacles met on the road will not make the car swerve from the line along which it is being driven.

Non-reversibility of the steering gear must not be absolute, or one of the wheels, not being able to deviate in the least, may be smashed against any obstacle. The worm gearing is already non-reversible, owing to the motion of the screw; but the screw absorbs much work and does not give rapid transmission. Jeantaud has patented an irreversible system, and de Coninck has constructed a mechanism with epicycloidal gear.

The Brillié epicycloidal transmission gear steering, which was employed in the Gobron Brillié cars, independently of its non-reversibility has the advantage of giving variable demultiplication of the motion of the steering. With a slight reduction of the demultiplication the car is turned more easily, but handling is more fatiguing; whereas with a great reduction handling is easy but turning is slower. In this gear, a hand steering wheel V (Figs. 455 and 456) is keyed on the top part of the steering axle A A^1, which is guided in a tube, T, upon which is fixed a toothed pinion, K; the lower part of A A^1 has a lever arm, L, terminated in a socket through which passes shaft D·D^1 parallel to A A^1. At the top part of D D^1 is a toothed sector, S, which gears with pinion K, and at its lower part is a crank arm, M, which moves the steering connecting rod, mounted on the pin C, perpendicularly

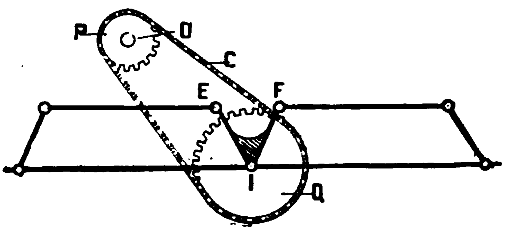


Fig. 454.

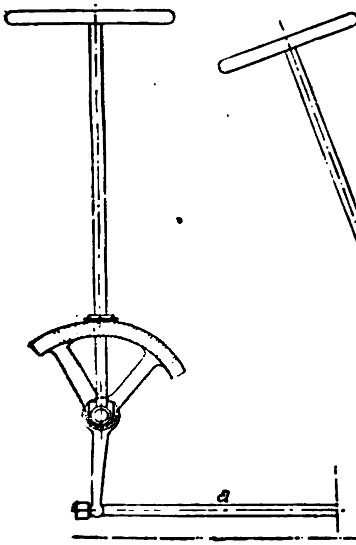


Fig. 451.

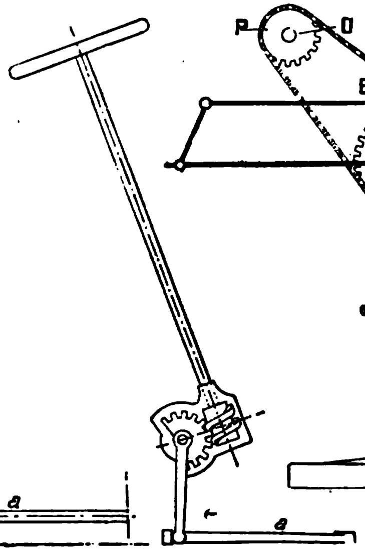


Fig. 452.

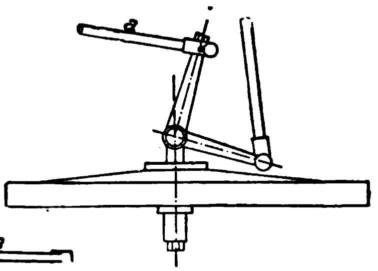
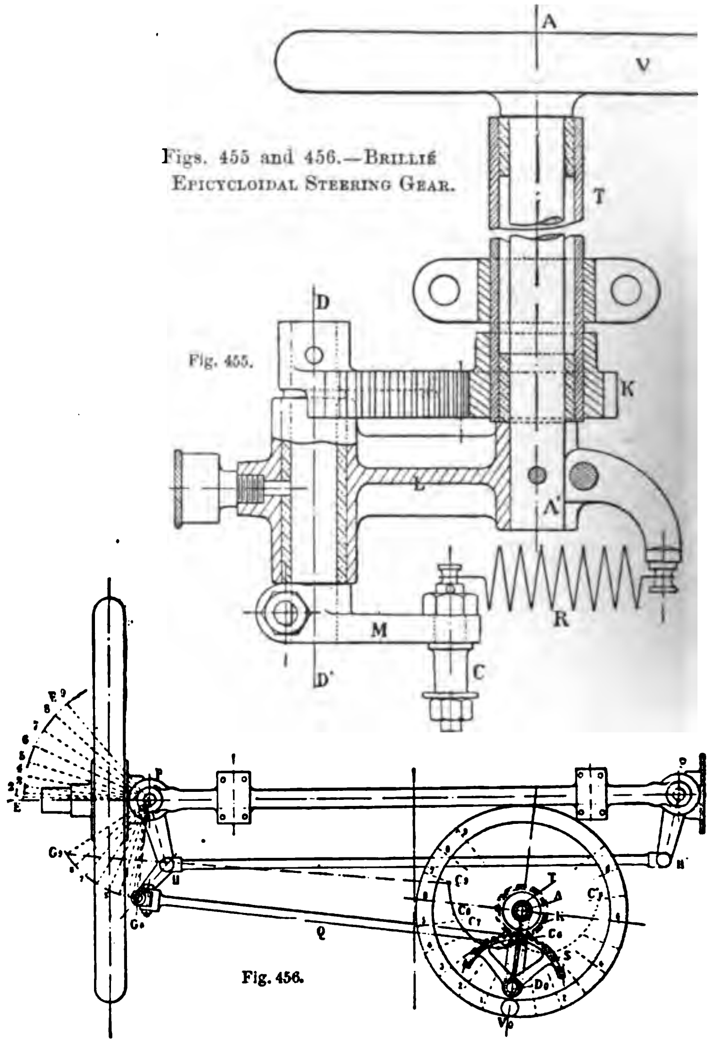


Fig. 453.

Figs. 451 to 453.—Panhard and Levassor Steering Gear.
Fig. 453 - Chain Steering Gear.

to the plane of the illustration (Fig. 455). Spring R constantly tends to bring the axes A C D back into the same vertical plane. If



Figs. 455 and 456.—Brillié Epicycloidal Steering Gear.

the hand wheel V is given a rotary motion, axis D will describe a circular path around A; the toothed sector S gears with the fixed pinion K, and every point of it and of the pin C will describe an epicycloid, an epicycloid being defined as the curve described by a point in a circle revolving in another. According as the hand wheel is turned to steer to the left or right, every point of C will describe a curve similar to C_0 C_9 or C_0 C_9^1 (Fig. 456). Now it results from the geometric properties of the epicycloid that if the hand wheel crank V is brought into positions equidistant, 1, 2, 3, 4, 5, 6, 7, 8, 9, the point C will occupy corresponding positions, namely C_0, C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, further and further from each other. If, therefore, point C is connected with the steering connecting rods by aid of rod Q, the latter will cause the former, which in turn acts on the wheels for equal displacements of the fly-wheel, to make ever-increasing angles of deviation according as one moves away from the rectilinear advance; this is clearly illustrated in Fig. 456. It results that, in order to deviate perceptibly from the straight line along which the car is running, the hand wheel must be displaced considerably; an involuntary movement given to the steering gear cannot therefore cause anything but neglectable deviations. It results also that to turn in a curve of small radius it suffices to make the wheel rotate one-third or one-quarter revolution. Moreover, owing to the action of spring R, shown in Fig. 455, and to the distribution of forces brought into play, the handle C and consequently the hand wheel V do not tend to deviate when the wheels meet abnormal strains caused by stones, etc.

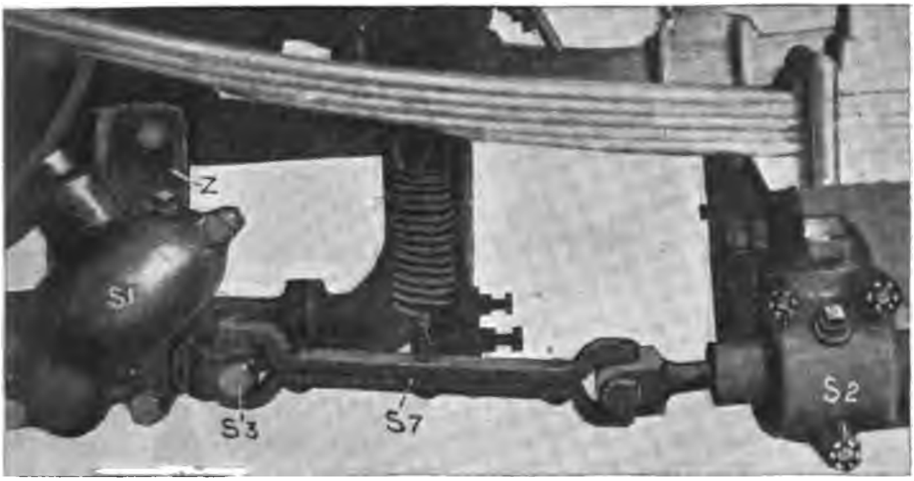


Fig. 457.—WOLSELEY STEERING GEAR.

The Wolseley steering gear has the advantages of the irreversible worm, whilst the steering is more sensitive than is the case with any direct form of steering. The hand-steering wheel is connected direct to a bevel wheel enclosed in the casing S^1, Fig. 457. This bevel meshes with a smaller bevel connected with the universal coupling S^3; and a connecting link S^7 transmits the motion of the smaller wheel to a worm, S^5 (Figs. 457 and 458), gearing with a worm wheel,

Fig. 459.

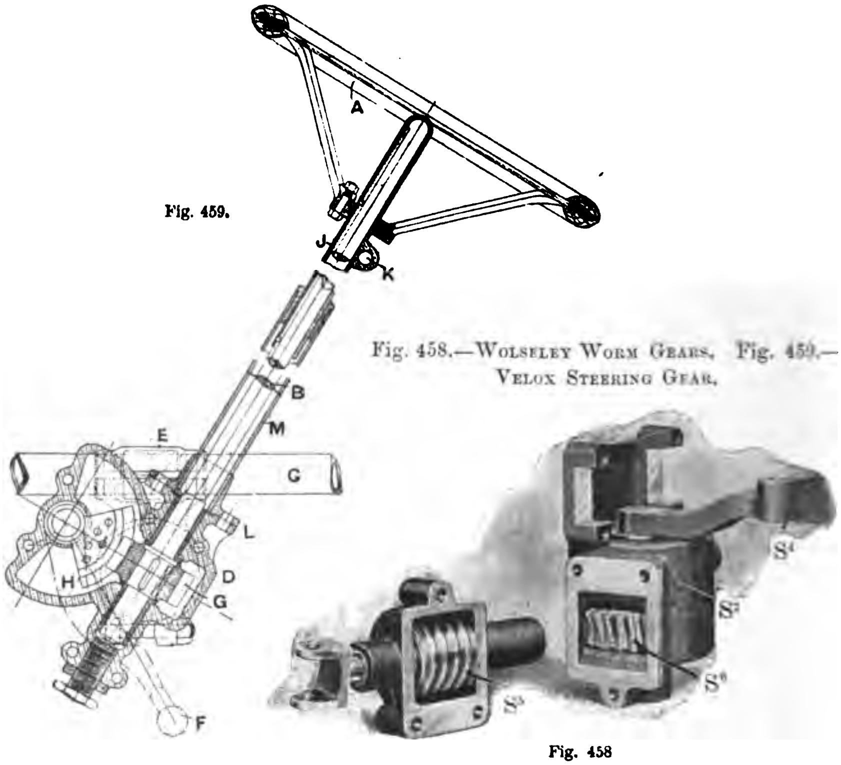


Fig. 458.—Wolseley Worm Gears. Fig. 459.—Velox Steering Gear.

Fig. 458

S^6, in a casing, S^2, bolted to the front axle. S^6 is rigid with arm S^4, and this is coupled by connecting rods, formed of two bars, to the levers projecting from the steering heads; these levers are not any shorter than usual. The bevel wheels gear up the motion given to the hand steering wheel, and the worm gear reduces it. The worm forms as usual the irreversible part, but the relative angular movement of the steering wheel and of the arm S^4 need not differ much To take up back lash caused by wear in the worm and worm wheel, a paper joint is made between the two parts of the casing S^2. The steering pillar is fixed to bracket Z.

The Velox steering gear is shown by Fig. 459. Its point of interest is the capability of adjusting the angle of the pillar M to suit the driver, and the telescopic attachment of the hand-steering wheel A to the centre rod B, so that the wheel can be fixed at any required height. In Fig. 459 C shows the tubular frame. For adjusting the angle of the pillar, the oil-tight casing D, enclosing the usual worm and segment, is so shaped that a circular portion of it fits into a bracket, E, which is clipped to the main frame C. This bracket can be moved forward or backward along the tube, and can be made to hold the casing D at any angle. The rod leading from lever F to the steering head can be lengthened or shortened to correspond with the adjustment of the pillar. The steering pillar M, is fixed to the casing D by a flanged joint, L, and encloses rod B, which carries the worm wheel G operating segment H; an outer tube J slides over the upper end of B, and is prevented from rotating by a feather key. The hand-steering wheel, A, is of special shape as illustrated, and is bolted to a flange on tube J; when this tube is adjusted to the required height it is clipped by a bolt passing through key K.

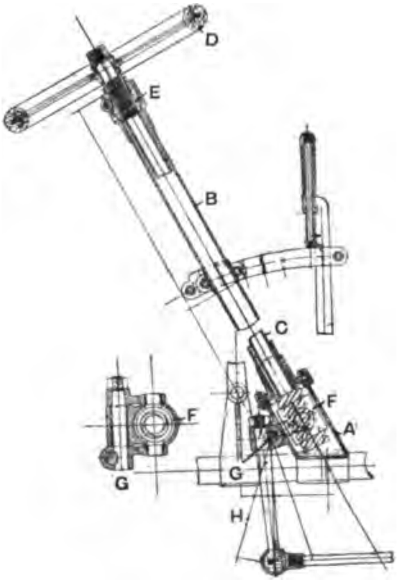
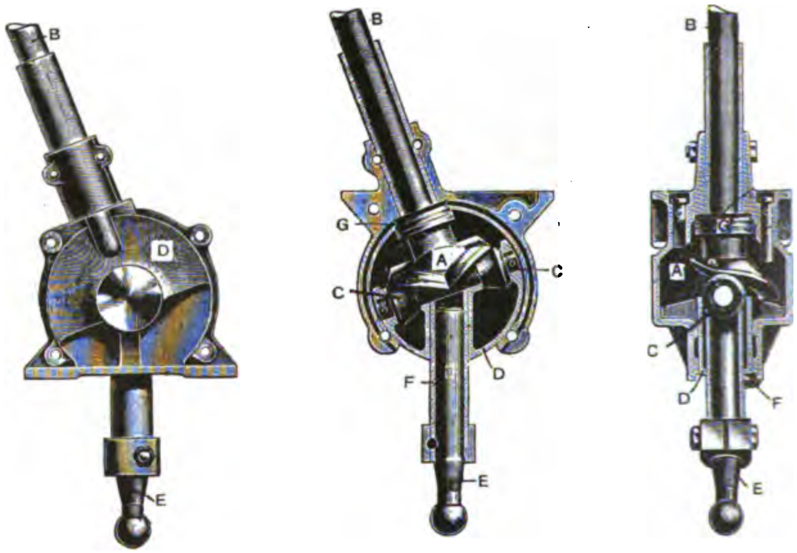


Fig. 460.—Ariel Steering Gear.

The Ariel steering pillar and worm gear are shown in section by Fig. 460. These parts are carried by the bracket A, brazed to the frame, and the pillar tube, B, is bolted by a flange fitting to the casting. This tube encloses the actual steering tube C, which is rigid with the hand wheel D, and is carried by a ball-socket joint E, in the top of the pillar. At the lower end of this tube is a fourfold worm on which rides a corresponding nut, F, which has projecting trunnions carried with lever arms rigid with shaft G. This shaft is mounted in a brass-bushed bearing provided by the casting A, and from it the arm H projects downward, and operates the usual system of steering rods. The centre of the nut F can move only through the arc of a circle about G, and the steering tube C, therefore, must be free to move sideways in the pillar tube B. These movements are provided for by the ball socket E, which also takes the thrust of the worm.

The Malicet-Blin steering gear (Figs. 461 to 463) is novel and interesting. There is the usual steering wheel on the rod B, at the foot of which is a disc-pattern cam, A, so shaped that its under face always presses against two conical hardened steel rollers, C, on opposite sides of its centre; whilst one roller is depressed the other is allowed to rise, both of them being kept in contact with the cam, so preventing back-lash. The rollers are carried on pins fixed to the cylindrical casting D, to which is secured the steering arm E, whose length is made adjustable by a telescopic joint, F. Movement of the cam forces the steering arm E backwards or forwards. The thrust of cam A is taken by a hardened steel collar, G, and there is provision for taking up any back-lash that may be caused by wear. Advantages of this arrangement are simplicity, irreversibility of the



Figs. 461 to 463.—Malicet-Blin Steering Gear.

steering gear when the car is travelling in a straight line, and extreme sensitiveness of steering; the further the road wheels are deflected from the straight, the less need the hand steering wheel be moved to deflect them proportionately further.

The Jenatzy-Martini steering gear, shown in section by Fig. 464 is carried on a substantial bracket, A, which is bolted to the underframe and provides the fulcrum bearings for the pedals B. The steering pillar C contains a hollow shaft, D, fixed to the steering wheel at its upper end. In Fig. 464 the lower part of this shaft is alone shown; the upper part is a separate tube, and is brazed to it. The shaft is prevented from moving longitudinally by a thrust bearing, E, and it has a compound feed screw, F, cut upon it; a nut, G, rides upon this feed screw and engages with the lever H, from the lower end of which the

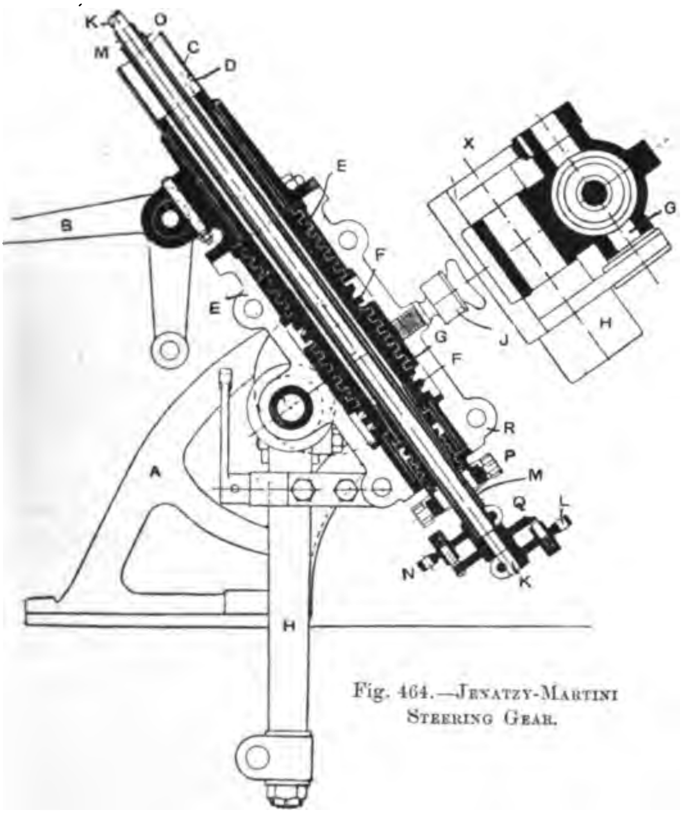


Fig. 464.—Jenatzy-Martini Steering Gear.

steering rod passes to the head of the off-side front wheel. The method of connecting the nut with the lever is shown in the separate cross section X. The travelling nut is lubricated from the greaser J. The shaft D is made hollow so that the levers which regulate (1) the lift of the inlet valves, (2) the time of ignition, and (3) the warm air supply to the carburetter respectively, can be placed above the steering wheel and can be connected with these parts by small concentric shafts passing down the centre. The central rod K carries the arm L at its lower end, by which it is connected with the carburetter butterfly valve spindle. The tube M surrounding the rod K carries the lever arm N, which in turn connects its lower end with the commutator. The tube O, which fits outside the tube K, is connected with the fitting P, which operates the inlet valve mechanism. The rod K and the sleeve M are prevented from moving freely, relatively to one another, by means of the flange Q, which is fitted between their lever arms L and N. Each of these arms contains a small spring plunger which presses against a friction face respectively below and above the flange Q. The outer tube O is provided with a feed screw, R, at its lower end; the corresponding nut fitting over the screw is part of the fitting P.

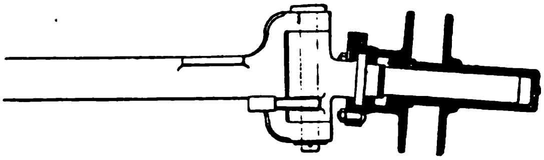


Fig. 465.—Lemoine Steering Axle with Chape.

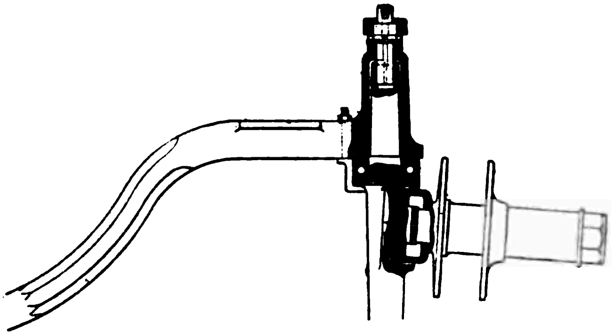


Fig. 466.—Lemoine Steering Axle with Vertical Pin.

The two pivot steering axles can be made in somewhat varied shapes; they have a chape as shown in Fig. 465, and a pin as shown in Figs. 466 and 467; the pin may be vertical or inverted with pivot or balls. Fig. 465 is a section of a Lemoine steering axle with chape; the steering lever is forged on with the journal; there is a half-patent metal oil nave for the wooden spokes. Fig. 466 is a section of a Lemoine steering axle with vertical pin, double oil box, and balls; the centred axle has an inserted journal to decrease projection; the patent metal oil nave has a counter disc without hoop for wooden spokes. Fig. 467 is an exterior view of a Lemoine steering axle with inverted pin, balls and pivot, flattened shoe, centred axle, metal nave, the pin seat being furnished with a lever forged on for steering. The two-pivot axle is employed almost universally.

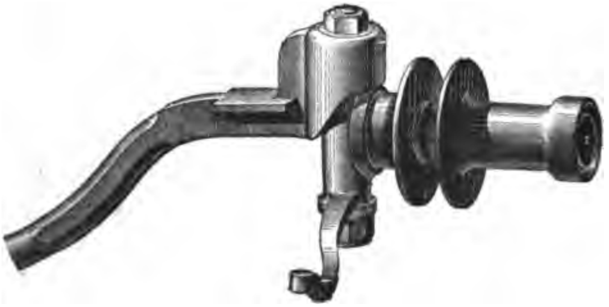


Fig. 467.—Lemoine Steering Axle with Inverted Pin.

It has been remarked that the pin or pivot fore-carriage also is used. It is adopted especially by Doré and by the Compagnie des Voitures Electromobiles. Some other systems are in use, but only by their inventors. For instance, Le Blant had two fore-carriage pin axles to facilitate turning forwards and make it possible to turn backwards. Bird's device was a pin fore-carriage with twin wheels very close together, the inconveniences of the large fore-carriage being decreased, but to the detriment of the stability. Duchâtelet's device compelled the driver to tighten the brake gradually before turning a corner, the sharper the turn the tighter being the brake.

CHAPTER XIII.

WHEELS AND TYRES OF AUTOMOBILES.

THE first quality requisite in the wheels of an automobile is solidity, for the impetus of the motor is transmitted to the carriage by their agency, and in sudden stoppages the strain on the wheels is greatly increased, and the wheels meet on the road with destructive shocks, which are proportioned to the kinetic energy of the car. Assuming that the load on the axle is only double that in a horse-drawn car, and the speed triple, it follows that the strength of a wheel of an automobile must be eighteen times greater than that of a horse-drawn car wheel to give the same degree of safety. But the requirements of safety with regard to wheels is not always fulfilled, a fact to which attention was called by the jury of the Liverpool 1898 heavy vehicle trials.

As regards the diameter of the wheels, in carriage-building there is a constant rule which is to make the diameter of the wheels proportional to their load. The advantages of large wheels are that they increase the lever arm to overcome the resistance due to friction of the journal in the box and decrease that opposed to rolling (Morin regarded the latter as being inversely proportional to the diameter), and they help the car to pass over obstacles in the road. The relation which gives the traction strain T to be developed to drive a wheel of weight P and radius R over an obstacle of height h is: $T = P\sqrt{\frac{h}{2R.}}$ A big diameter is yet more efficient when big obstacles have to be met. Big wheels wear out the road less than do small, heavily loaded wheels, which have a very destructive influence on roads; also the big wheels cause less dust, at an equal tangential speed they turn less rapidly than small wheels, and suspend the body of the car and the motor at a greater height above the ground. The inconveniences of large wheels are that they are very heavy, and that the power being applied to the nave whilst the tyre meets the resistance, the spokes tend to bend, and the greater their length, the greater the bending. As a rule, the resistance of a wheel is calculated as the inverse proportion of the square of the radius compared with the strains it exerts vertically in the plane of the wheel, and as in inverse proportion of the cube of this radius compared with the transversal strains it has to undergo more accidentally. Bending can be prevented by a device similar to that employed by de Dion-Bouton, who applied the power to the felloes. Another disadvantage of big wheels is the risk of warping, owing to chain transmissions having led to the adoption of journals without setting, and consequently wheels that are not dished; but now it is possible to employ chains for wheels mounted on slightly set journals. Big wheels are more difficult to lodge, and it is necessary to increase the space between the wheels; also turning demands greater space. Cars mounted on big wheels are higher, and consequently not so stable, but crank axles can be employed, in which case increase of the size of the wheels causes stability. With big wheels the speed has to be reduced more when turning, and in consequence of this the transmission gear is more complicated. But as the consideration of safety comes first, solidity must be assured before all else, and as wheelwrights learn to make more durable wheels their diameter can be augmented.

Automobile wheels have been made low, especially for vehicles carrying a number of passengers. In the Scotte 1897 omnibus the diameter of the fore-wheels is 0·770 m. (30·31 in.) for a load of 1,280 kg. (2,816 lb.), and that of the near wheels 0·900 m. (35·4 in.) for a load of 1,945 kg. (4,279 lb.). In the de Dion-Bouton 1897 omnibus the diameters are respectively 0·8 m. (31·5 in.) and 1 m. (39·37 in.) for loads of 980 kg. (2,156 lb.) and 2,100 kg. (4,620 lb.). Few modern cars exceed this, though in the Brightmore lurry the wheel diameter is 104 cm. (3 ft. 5 in.); Musker and Leyland lurries 91·4 cm. (3 ft. 3 in.). These are tall, but are not so big as the largest wheels employed for ordinary carriage building. A typical light steam car, the Locomobile 10 h.p. dos-à-dos, has wheels 71 cm. (28 in.) in diameter. With regard to petrol cars, in the English Daimler and Brooke cars the wheel diameter is 91·4 cm. (36 in.); Richard cars, from 75 cm. to 87 cm. (29·5 to 34·25 in.); Rochet-Schneider, 90 cm. (35·4 in.); de Dion-Bouton "Populaire," 68·6 cm. (27 in.); Renault, 80 cm. to 90 cm. (31·5 in. to 35·4 in.); and Velox, 81·3 cm. (32 in.).

It would be well to make the fore-wheels of the same diameter as the rear ones, considers Forestier, so as to be able to load them equally, and so decrease the risk of the car's swinging round, the length of the axle being increased to allow of the same steering angle without reducing the width of the frame and body.

Tyre width now may be considered. On horse-drawn pleasure cars the tyres frequently have a width of 1 mm. per 5 kg. (1 in. per 280 lb.) of load; in diligences 1 mm. per 10 kg. (1 in. per 560 lb.). There is a pneumatic tyre width of 25·4 mm. (1 in.) on the Star petrol car for about every 193 kg. (425 lb.) of weight; for every 83 kg. (218 lb.) on the Duryea: for every 207 kg. (457 lb.) in the de Dion-Bouton "Populaire"; and for every 216 kg., 264 kg., or 317·5 kg. (477 lb., 583 lb., or 700 lb.) in three types respectively of Locomobile cars.

There is no distinct and accepted theory respecting the width of tyres. Morin maintained that wide tyres increase the resistance to rolling on a hard road and decrease it on a soft one. Dupuit considers that widening the tyres has no effect on macadamised roads, but a favourable effect on pavement. De Mauni says that a wide tyre is preferable for sandy, very dusty or very muddy roads, but the opposite with a thin layer of sticky mud. De Mauni recommends that a long narrow contact surface be given to the wheel tyre.

These contradictions are more apparent than real, because so much depends upon the condition of the roads experimented with. Thus, on a compressible road there is an advantage in widening the tyre, but if the road is also scattered over with pebbles a wide tyre will increase the number of obstacles met with. Methodical experiments are wanted to settle the width which has most chance of giving best results for a number of more or less complex circumstances. In the case of heavy vehicles, the necessity of a good road must be emphasised. The trials at Liverpool in 1898 made this clear. The imperfections of ordinary roads are the chief source of the great cost of maintenance and also the principal factor of the risk attached to all systems of mechanical road traction.

In order to avoid making deep wheel marks, as these impede traction, the surface of the wheel in contact with the ground must be increased and, length of contact being equal, the narrowest contact will be the best, because with it the tracks will be slightest. The only way to lengthen the contact of rigid tyres is to increase the diameter of the wheel, a matter that has been discussed already. Often enough tyres have to be made rather wide to obtain as much as possible of the condition for minimum traction.

Wheels can be classed under three chief headings: (1) wheels with wooden spokes; (2) wheels with metal spokes, and (3) solid metal wheels.

Wheels with wooden spokes may have the nave made of twisted elm to avoid clefts, but preferably the nave is of bronze, case-hardened iron, or cast steel. Figs. 468 and 469 represent two bronze naves as made by Hannoyer, the first being mounted on an iron box and the second forming a box in a single piece. For heavy vehicles the spokes are made of acacia wood or oak; the former polishes better than oak and is tougher, and for these reasons is preferred for fine carriage work; but it is difficult to find it thick, and in any case it has not the solidity of oak.

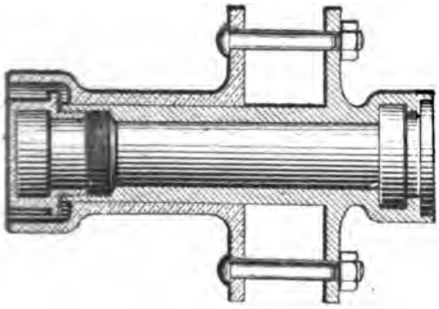


Fig. 468.—Bronze Nave mounted on Iron Box.

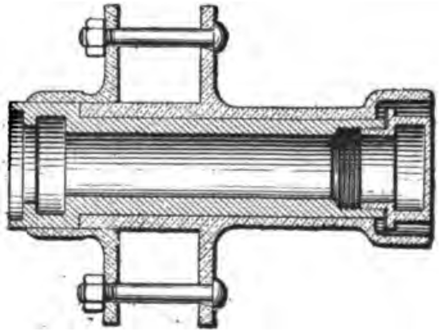


Fig. 469.—Bronze Nave forming one with Box.

The felloes of wooden wheels are made ot ash, more rarely elm, and sometimes metal. As the journals cannot be given the ordinary set the wheels cannot be dished much, though sometimes they are slightly dished; dishing somewhat decreases the solidity of the wheels, but it makes them more elastic. Also, the set of the axle and the dishing of the wheel make cars roll better.

Wooden felloes are employed on wooden wheels usually, and then the number of spokes is always double that of the felloes; these are in odd numbers (7 or 9). They are fastened by aid of wooden pegs, and so fixed that the large axis of their elliptical section is placed transversely. When they have to support the toothed chain wheel, this is bolted to bosses by which the wheels are reinforced. The spokes are secured to the felloes by shoulder tenons and mortises.

With metal felloes the spokes are fitted into metal sockets which are bolted to the felloe (Fig. 470). Tenons and mortises are employed to fasten the spokes and nave, whereas with a metal nave the spokes are usually pressed together between two plates united by bolts placed between the spoke joints.

Wooden wheels wear very well, and are much more in vogue than wheels with metal spokes. However, they have to be tightened from time to time to remedy the looseness due to wear and hygroscopic variations which affect the spoke ends. To avoid this Gerard invented a device whose performances are not sufficiently known to permit of a decisive opinion being expressed on its merits, and since then the Établissements du Creusot has patented a system.

The Mulliner double artillery wheel (Fig. 471) is claimed to resist the side strains imposed when rounding a corner or running at a slight angle across such obstacles as tramway lines. The spokes are in two sets, not at right angles to the axle, each set springing from one end of the wide hub and having its outer ends slightly staggered where they fit into the felloe. The extra strength of the wheel is due to the spokes not having to take any side strain at right angles to themselves, but convert a component of the side strain into a direct down thrust. Its weight is not greater than that of the ordinary wheel.

The devices employed in order to render possible the setting of the axles and the dishing of the wheels are nearly all based on the employment of toothed gear, as is that of Foucher and Delachanel, for instance; the chainless systems of de Dion-Bouton and others, already described amongst the systems of transmission, also enable setting and dishing with very good results.

The second class of wheels have steel spokes of small section; these wheels cannot work in compression as wooden ones do, but only in tension. The axle not being supported by the spoke below the nave that spoke, bending beneath the weight, is suspended by the one above to the top part of the wheel. The spokes get larger in section from nave to felloe. The spokes are always arranged so as to give the wheel the aspect of two flattened cones welded by their base. This double dishing gives the wheels the advantage of resisting, in both directions, lateral shocks so frequent against kerb-stones and against rails without guards. The spokes may be direct or tangential. Direct spokes are placed radially, and to fix them in position they are run through a hole in the felloe, against which they rest by a projecting part, and the end is screwed in the nave; the useful length is regulated by a nut. The tangential strain they support causes them to bend in the direction in which the car travels. Tangential spokes run from the nave to their concentric circumference, and they are fixed by the head to the nave and screwed to the felloe. They run half in one direction, half in the other, so that the driving may be forwards as well as backwards; they resist the moment of torsion better than others; this torsion tends to be produced from the nave to the felloe when the latter is abruptly stopped by an obstacle. Figs. 472 and 473 represent two types of naves for metal spokes invented by Lemoine; Fig. 474 gives a vertical section of the nave and a section of the felloe of a wheel with metal spokes formerly made by Peugeot, who first adopted metal for car-wheel spokes, previously employed only for motor-cycles and voiturettes; the spokes are medium hard steel, resisting 100 kg. per mm.^{2} (63·49 tons per square inch) of section, and there are ball bearings. Metal spokes are lighter than wood, but they must be made perfect.

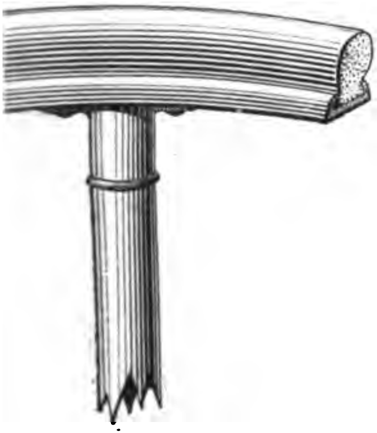


Fig. 470.

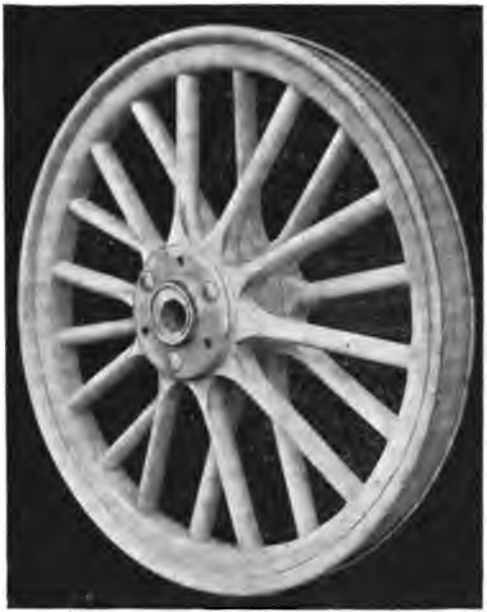


Fig. 471.

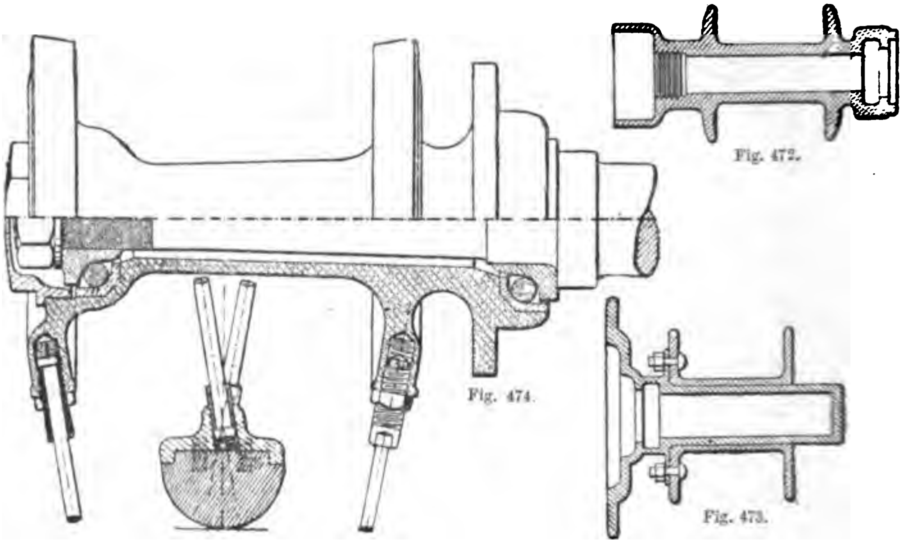
Fig. 470.—Spoke in Bolted Socket.

Fig. 471.—Mulliner Double Artillery Wheel.

Solid metal wheels are quite a recent application. Those of the

New York Electric Vehicle Company have solid segments instead of spokes made of steel, 4 mm. (·157 in.) thick, arranged in the same truncated cone surfaces as ordinary spokes, so as to leave between them a greater space near the nave than near the periphery, where they are separated by a wooden felloe shaped in section like a crescent to receive the pneumatic tyre.

With regard to wheel tyres, passenger cars are furnished exclusively with indiarubber tyres, which are essential at great rates of speed for the comfort of passengers and the preservation of the mechanism. Heavy cars of slower speeds generally have metal tyres, but the last few years have witnessed a marked tendency to adopt indiarubber. The plates of fine iron of the best quality are centred cold when the diameter of the tyre section is very great, and hot in the opposite case. The ends are then welded so that the interior diameter of the tyre will be exactly equal to the exterior diameter of the felloe; the tyre is fixed hot to the felloe. The hammering to which the tyre is subjected chiefly on pavements exerts destructive effects on iron, especially when the wheels are heavily loaded. Maurice Le Blant successfully employed for tractors and brakes tyres 75 mm. (2·95 in.) wide of (*a*) iron of usual thickness, which



Figs. 472 and 473.—Lemoine Naves for Metal Spokes.
Fig. 474.—Peugeot Nave and Felloe.

snapped very soon; (*b*) iron 40 mm. (1·57 in.) thick, which was crushed according to the working off in rolling; (*c*) steel 40 mm. (1·57 in.) thick, which was soon crushed considerably; the tyre had acquired a width of 90 mm. (3·54 in.) at the exterior circumference, though it retained that of 75 mm. (2·95 in.) at the inner circumference. However, the steel was extra soft, and hard steel would have resisted much better. G. Brabant recommends steel giving a rupture strain of from 65 kg. to 70 kg. per mm.^{2} (41·26–44·4 tons per square inch), manufacturing it in the rolling mill like a wagon tyre.

Solid indiarubber tyres must be secured firmly to the felloe to prevent parting, which would make the car unfit for work, and might even cause serious accidents. They should be made wide enough not to enter tram rails. They are fixed to the felloe by (1) pressure, (2) cement, or by (3) circular bands with or without bolts. For the pressure method, the metal felloe is U-shaped, each branch being bent upwards so as to enclose the tyre in a cavity with a dovetail section which secures it when pressed. This system enables a tyre to be fixed or removed without sending the wheel to the works. There is the disadvantage that the part forming the lugs of the dovetail is almost lost as regards elasticity; the indiarubber should not pass beyond the iron, which would then work in space. Angular parts must be avoided in the felloe profile which, under the influence of pressure, might tear the tyre. The profile of the Vinet felloe (Fig. 475) appears to be devised well, because the indiarubber exerts pressure on all the various points and it is inserted sufficiently deep to hold the tyre, which also is fixed to the felloe hot with gutta-percha cement. The Clincher and certain Hannoyer wheels also have pressed tyres (*see* Fig. 476). In the Loubière system (Fig. 477) the inserted part is not thick, and elasticity is not lost; transversal pins retain the indiarubber.

Buffer solid tyres (Fig. 478) are as simple as any in use; the rubber merely fits into the steel rim and is held there by pressure.

For cementing on the tyres, the U-shaped felloe has straight branches; first it is coated with indiarubber solution and a band of strongly vulcanised indiarubber is applied; then a second band less vulcanised is put on, and finally the tyre. All is heated in a steam chest usually at 140° C. (284° F.) for two hours, to give it the proper cohesion. This system is said to deprive the indiarubber of some of its natural elasticity; this is true for the two vulcanised bands, but to a much less degree for the tyre itself. This system necessitates the wheels being sent to the works for the tyre to be changed or merely repaired, and it forms a general structure defective in uniformity. Cemented tyres, when well made, wear quite well enough, say the manufacturers, for from 5,000 km. to 8,000 km. (roughly, 3,100 to 5,000 miles). Both Torrilhon and Hannoyer employ this method. Torrilhon's tyre is shown by Fig. 479. Hannoyer sometimes fastens the first band of indiarubber to the tyre with screws whose heads are buried in the second band of vulcanised indiarubber (*see* Fig. 480). Hannoyer and Bouquillon adopted this process for wooden felloes, to which metal rims are attached by long screws to which the tyre adheres (*see* Fig. 481). As the heat required for vulcanisation on iron would destroy the wood, it is necessary, once the metal rim is applied hot, to withdraw it and not replace it till after heating.

When circular bands without bolts are employed, the felloe is U-shaped and bell-mouthed, the solid indiarubber being retained in it by two steel rods, which form its core and run with it all round the wheel. The widening out of the felloe prevents the tyre from ever being caught between the edge of the felloe and the ground, and runs no risk of being cut. As the length of indiarubber employed is greater than the circumference of the wheel, it suffices to remove the damaged part without replacing it; if too long, another is substituted for it, but all the rest of the tyre can be used again. This system ought to make the tyre untearable. It is employed by Kelly, who uses as bands soft steel wires, electrically welded (*see* Fig. 482). Hannoyer twists the wire mechanically instead of welding it, and the twists prevent the indiarubber gliding along the wire, as, moreover, do the transversal projections on the metal rim (Fig. 483).

Circular bands with bolts are employed on the Ducasble tyre (Fig. 484), which has a groove with triangular section on the inside into which a hollow tube of the same shape fits. In the centre of the base of the tube there is a groove through which the bolt heads are placed and then moved round one quarter turn to bring their lugs to a right angle with the edges of the groove. The stems of these bolts run through the steel U-shaped rim, which receives the tyre and, if necessary, the wooden wheel felloe; each bolt is tightened by a small nut screwed on the end. The joint of the tube is made to fall between two bolts nearer than the others and not vertical to the tyre joint, the two ends of which are cemented with indiarubber

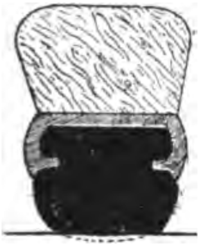
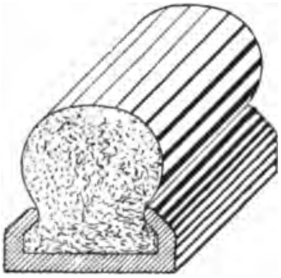


Fig. 475.



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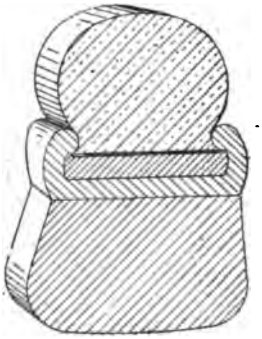


Fig. 477.

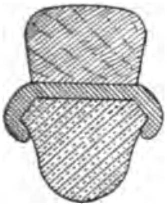


Fig. 478.

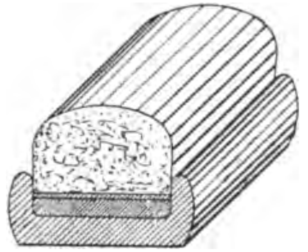
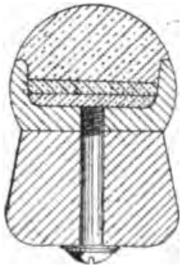


Fig. 479.



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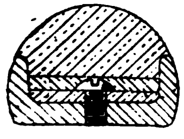


Fig. 480.

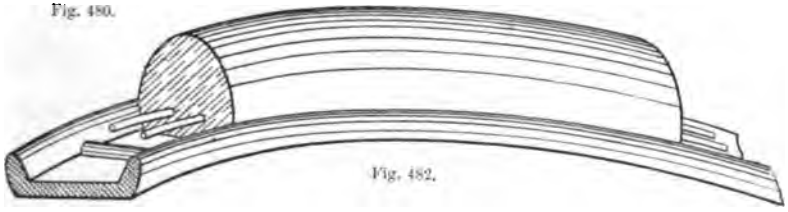


Fig. 482.

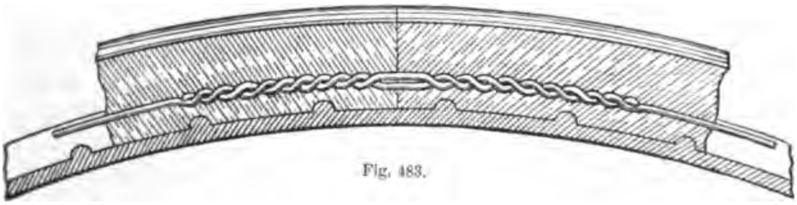


Fig. 483.

Fig 475.—Vinet Pressed Tyre. Fig. 476.—Clincher and Hannoyer Pressed Tyre. Fig. 477.—Loubière Pressed Tyre. Fig. 478.—Buffer Solid Tyre. Fig. 479.—Torrilhon Tyre. Figs. 480 and 481.—Hannoyer Tyre and Bouquillon Tyre Screwed On. Fig. 482.—Kelly Tyre with Wires. Fig. 483.—Hannoyer Tyre with Twisted Wires.

solution. The inventor claims for his system impossibility of tearing away, possibility of employing a very elastic indiarubber merely surrounded by a cloth, which wears better than hard vulcanised indiarubber, and (3) the facility of removal and fixing, and the replacing of worn parts.

The Peters solid tyre (Fig. 485) is moulded round the steel band A; B indicates hard rubber, and C a softer kind. It is fixed by very simple means. The smooth rim D has a fixed flange, E, and a detachable one, F; when the latter is removed the tyre is slipped on, the flange replaced and tightened up by means of a screw with a right and left hand thread. Similar means are adopted for securing the Peters pneumatic tyre.

Perhaps the heaviest tyre in use is the Goodyear (Fig. 486) with a diameter of 12·7 cm. (5 in.); its application to the wheel is novel for a solid tyre, being practically identical with that employed for the Goodyear pneumatic (Fig. 496, p. 469). . In addition to cross bolts, A, passing from one detachable rim flange, B, to another, stout steel wires, C, are embedded in the base of the tyre lengthwise, below them being a number of small wires (not shown) arranged transversely, so as to form a kind of wire fabric inside the base of the tyre. In addition, there is a special fabric whose layers are capable of moving over one another. D is the rim, and E the felloe to which the side flanges are bolted by F.

The Gare tyre has a steel tread, A, Fig. 487, shrunk over a tube, B, which is hollow or filled with suitable material, C; this rests upon a rubber cushion, D, held in the steel rim E, fitted upon a wooden felloe, F. The object is to distribute the pressure over a large section of the rubber cushion.

Compound tyres are solid tyres, bu the interior is formed of a more elastic material so as to give about the same resistance as a solid tyre with some of the pliancy of a pneumatic. The tyre (Fig. 488) is a jointless ring moulded separately with a pure indiarubber core and a less elastic and more resisting indiarubber exterior. It is secured by bolts and wing nuts to the steel rim, which has very broad flanges or ribs to protect the indiarubber and, if necessary, the wooden felloe against lateral shocks and friction.

The hollow or cushion tyre is not suitable for an automobile: at most it might be employed for a motor-cycle or a voiturette, though pneumatic tyres are always better.

In hollow indiarubber tyres, when under the great pressure from the car, the resistance of the air in the hollow part is not sufficient, so that it seems the tyres merely are equivalent to solid ones with a reduced section. To make them resisting enough, Torrilhon forms the air chamber of a series of cells separated from each other by radial partitions. This air chamber is cemented to the other part of the tyre which surrounds it, and this in turn is cemented to the metal rim. Ducasble's tyre (Fig. 489) has a space above the metal tube; this tube has a tough rectangular section.

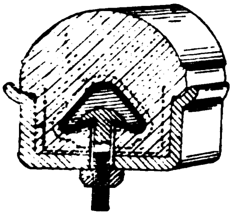


Fig. 484.

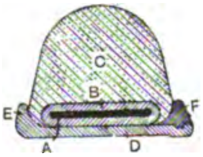


Fig. 485.

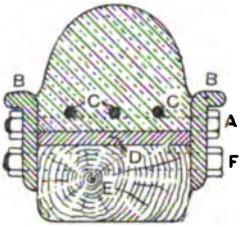


Fig. 486.

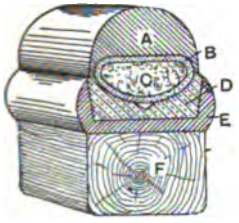


Fig. 487.

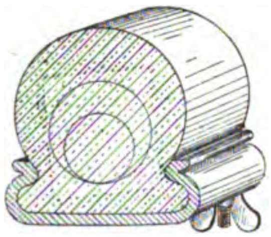


Fig. 488.

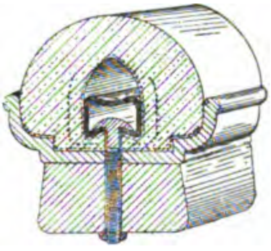


Fig. 489.

Fig. 484.—Ducasble Tyre, with Band and Bolts. Fig. 485.—Peters Solid Tyre. Fig. 486.—Goodyear Solid Tyre. Fig. 487.—Garr Solid Tyre, with Steel Tread. Fig. 488.—Typical Compound Tyre. Fig. 489.—Ducasble Hollow Tyre.

The Sewell cushion tyre (*see* Fig. 490) appears to be composed of rubber balls, projecting at intervals from a flat tread raised slightly above the wheel felloe. Actually, each "ball" is a hemispherical, hollow piece of rubber, A, with a square base, to which is cemented a flat sheet of rubber; a hard rubber plug, C, forms a key in the lower part of the chamber; the square base D is tapered to fit the flanged rim E. Below each hemisphere the wheel felloe F is cut away, so that the air in G cushions the compression of H. The tyre is made up of a number of these sections, secured by metal plates arranged radially on edge between them, and keying into the flanged rim. Small, hard rubber wedges are forced in between the plates and the rubber blocks; in the plates are slots into which fit other metal plates, shaped to encircle half one of the projecting hemispheres. When these second plates are forced down into place. they touch each other at the sides of each hemisphere, and are not liable to get displaced when in use. When unloaded and running slowly, a single tyre has a "bumpy" action, but this is hardly perceptible when the weight and speed are greater. The tyre is barely affected by the puncture of one hemisphere, which can be left as it is for a time or replaced very quickly.

Another ball tyre is the Germain-Littinger, which has a number of inflated oval balls, with thick rubber treads, mounted equidistantly. The rubber base has side beads fitting into the rim flanges.

The Ferrée cushion tyre has an inner tube of rubber balls strung on a cord and held apart by separators. There is a thick outer cover.

Pneumatic tyres are becoming more and more common, in spite of punctures, bursts, and expense of repairs.

They greatly soften vibrations and decrease the traction strain. Michelin's experiments clearly demonstrated these facts. De Mauni has demonstrated that of two wheels equally loaded and with equivalent contact surfaces the wheel that rolls the better is that with the most elongated contact. In the case of a wheel with rigid tyre this elongation can be obtained only by an increase of the diameter, always very limited, so that the wheel makes a track and sinks proportionally to the load of the vehicle. With an indiarubber tyre, on the contrary, elongation of the contact is obtained not from the diameter but the elasticity of the rolling surface; here, instead of leaving a track and sinking, moulding the ground, the tyre yields, spreads out until the area of contact is sufficient for the sum of the pressures to equilibrate the weight of the system. From this it can be understood why the indiarubber tyre decreases the resistance to rolling, and also why the pneumatic tyre is superior to the solid; the first becomes elongated under the weight of the wheel differently from the second. Elasticity limits the effect in the solid tyre to the part near the ground, which is for the moment compressed, whereas in the pneumatic tyre effects of this compression instantaneously spread over the circumference of the tyre, the seat of the elasticity here being an air cushion under pressure the molecular actions and reactions of which are propagated without perceptible work.

The pneumatic tyre has one defect apart from the liability of punctures. As has been said, in order to reduce the resistance to rolling it is necessary to make the contact surface as long and as

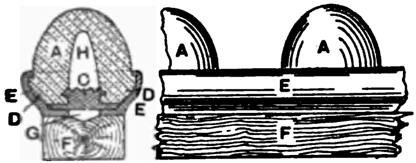


Fig 490.

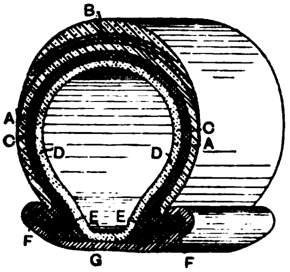


Fig. 491.

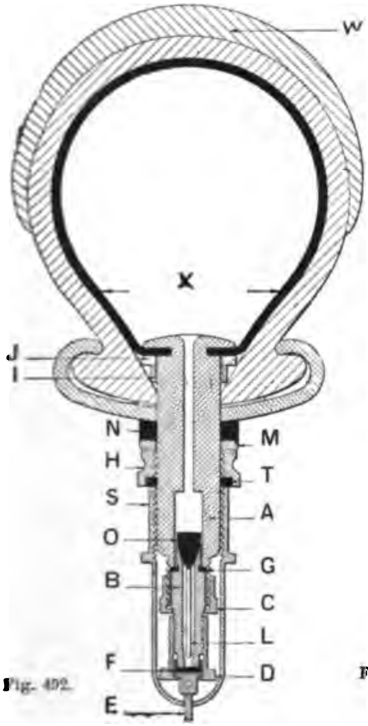
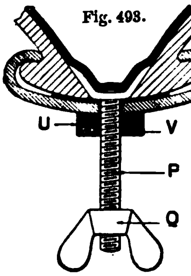


Fig. 492.

Fig. 493.



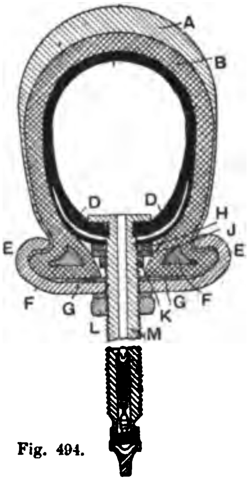


Fig. 494.

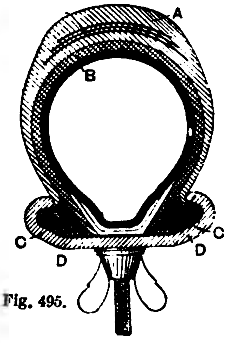


Fig. 495.

Fig. 490.—Sewell Ball Tyre. **Fig. 491.**—Dunlop Pneumatic Tyre. **Figs. 492 and 493.**—Michelin Pneumatic Tyre and Bolt. **Fig. 494.**—Goodrich-Clincher Pneumatic Tyre. **Fig. 495.**—Clipper-Continental Pneumatic Tyre.

narrow as possible; whilst the tyre elongates under the pressure of the car it also expands transversally. This is a defect, and explains why, at a given moment, an increased traction strain may result from a greater elasticity, and why, consequently, when the road is good, the tyre should be inflated to the fullest extent. The question as to what is the best degree of inflation thus is very complex, being dependent on the variable condition of the road; probably a very lucid answer to the question cannot be given.

The pressure of the air on the chamber of a pneumatic tyre is about 4 kg. per cm.^{2} (56 lb. per sq. in.) with light cars, and from 5 kg. to 6 kg. per cm.^{2} (71 lb. to 85 lb. per sq. in.) with heavy cars. The diameter of the tyres is on the increase, and Michelin now manufactures some having a diameter of 120 mm. (4·7 in.), and the Anciens Établissements make some 130 mm. (5·1 in.) in diameter for 2-ton cars, and certainly the size will be increased further. In wheels with metal spokes the tyre is fixed to the rim, which itself is fixed to the spokes. In wheels with wooden spokes the metal rim to receive the tyre is applied hot on the wooden felloe, to which it is secured by flat-headed screws; sometimes, however, there is no wooden felloe and the metal rim is applied hot on the metal sockets on the spoke tips, to which it is fastened with flat-headed screws or rivets.

There is a great variety of pneumatic tyres for automobile use, and nearly twenty are described briefly below; but not many more than half that number—and they are those immediately following—are in popular use.

The Dunlop pneumatic motor tyre formerly was wired on, but this type is only supplied now to fit existing rims, and the new beaded edge tyre (Fig. 491) is the one recommended by the makers. The outer cover A has a thick rubber tread, in which are a few strands of fabric, B, on the inner side being thick canvas, C. D shows the inner tube. The hard rubber E assists the bead F to keep a good hold of the rim G, which is secured to the felloe with bolts and wing-nuts. The Dunlop non-skidding cover has given highly successful results; it has semicircular cross grooves nearly 19 mm. (·75 in.) wide at intervals of about 25·4 mm. (1 in.); the tread is particularly thick, the thickness at the bottom of the grooves being the same as in an ordinary cover.

The Michelin pneumatic tyre is shown in section with the valve by Figs. 492 and 493. It is maintained in the steel rim by two flanges, which wedge each other in the tyre hooks by four bolts, similar to that shown in Fig. 493, which terminate inside by a V, the two branches of which nip the flanges and the wheel rim and complete the adherence of tyre and wheel. In Figs. 492 and 493 A is the valve body, B the valve central piece, C nut, D cap, E spindle, F indiarubber disc, G N and U indiarubber washer, H large nut, I nut within rim, J plate, L needle, M and V copper washer, O obus, P bolt, Q wing nut, S hood, T leather plug, W protecting tread of outer cover, X air chamber.

Practically the same tyre is known in France as the Michelin, in Great Britain as the Bartlett-Clincher, or Clincher-Michelin, in Germany as the Continental, and in America as the "C and J," or Goodrich-Clincher tyre. Fig. 494, showing one kind of the last-named, may be compared with Fig. 492. In Fig. 494 A is the outer cover, B the inner canvas layer—the inner tube is thickened and fabric-strengthened at D—E is the rim, F shows hard rubber "clinchers," G rim protection strip, H washer, J bridge, K bridge nut, L lock nut, and M valve stem.

The Clipper-Continental tyre (Fig. 495) has a broad tread, A, sometimes corrugated to oppose skidding. B is the inner tube. The beaded edges C fit into the rim D. Another kind of Clipper-Continental tyre has round metal studs with heads or faces containing cross corrugations which form numerous points. They are let into the thickened tread, and screwed into metal seats embedded in the canvas of the outer cover. The studs wear away more quickly than the rubber, and can easily be unscrewed and replaced with fresh ones.

In the Goodyear tyre (Fig. 496) the outer cover comes together near the felloe in two thick rings of solid rubber, A A^1, which are held together by detachable rims and bolts, B. Bolts C D secure the rims to the wheel felloe, and to remove or replace the tyre only one rim need be taken off. The inner tube K is protected by a rubber flap from injury where A A^1 are brought together. Thin wires, W, cross one another throughout the whole circumference of the solid portions of the tyre; and as the tyre expands with pumping, the expansion tends to shorten the effective length of the twisted wires and so grip the tyre more firmly to the wheel felloe. Fabric J is woven into the outer case. A set of these tyres is stated to have run nearly 13,000 km. (8,000 miles) on a 30-h.p. Daimler car without puncture or accident.

The Collier tyre (Fig. 497) has a very thick rubber tread, A, the outer cover B being well strengthened with canvas. The rim C is flat, the curve of its projections, D, being very slight. The tyre is secured around the rim by galvanised rods, E, inside wire spirals, F, and the makers emphasise the absence of "creeping," that is, relative rotative movements between tyre and rim. G is the inner tube.

The outer cover of the Toni tyre (Fig. 498) ends in square portions A, which fit into rebates cut on the wheel felloe B, which has a well-secured steel rim C, wider than the felloe itself; the ends A fit in between the rim C, felloe B, and flanges D, the last-named being secured by bolts, E. The cover contains three pieces of canvas providing six plies, F, in the wall, and nine plies, G, in the tread; the canvas passes round the inside of the cover, then around the hard rubber cores forming the parts A, and then both of its edges are carried round so as to interlock at the top. One object of this is to avoid the edges ending at any place where they are exposed. The canvas layers are in contact with each other, and are not insulated with rubber. In manufacture the canvas part is given a layer of soft rubber, H, and partially vulcanised before adding the hard rubber tread J. In Fig. 498 the thickness of the canvas G in the tread is exaggerated to better show the build of the tyre; actually there is a thickness of the soft rubber H between the canvas G and the hard rubber tread J. The threads of the canvas are at an angle across the tyre. Hard rubber tongues, K, are fixed to the cover, and lie upon the steel rim C to prevent the nipping of the inner tube L between cover and rim. The shape of the inner tube and its position relatively to the felloe have been determined with a view of preventing rolling, and so avoiding disruptive action on the cover between the flanges D and the rim C.

The Fisk is an American tyre (Fig. 499) employed on the Locomobile new dos-à-dos. Its air chamber is quite outside the rim, which, indeed, is flat where the tyre is attached. The outer cover has projections which are held down to the rim by clips acting on metal rings. The inner part of the outer cover is of canvas, and there is an inner tube. The Jackson duplicate tyre (Fig. 500) has a broad base; between the two inner tubes A is a flexible canvas partition, so that when one tube gets punctured the other may be given extra inflation, sufficient to keep the tyre in use. The tread and outer cover C is secured to the rim D with metal flanges, E, and these are tightened by a screw not shown. Each inner tube has a valve connection, F. The Holborn tyre in section shows a pointed, hard rubber band shaped like a Gothic arch. The elliptical inner tube has a thick canvas covering and pointed soft rubber nose. A rim is embedded in the canvas covering of the inner tube, and it is secured to the wheel rim by bolts and fly-nuts. The shape renders punctures difficult, and the inside canvas is further protection.

The Rucker unburstable tyre (Fig. 501) has a rubber tread, A, containing a band formed of several layers of thread wound circumferentially and prevented from spreading sideways by a single canvas layer, B. An inner band, C, is built up of alternate blocks of wood and rubber of the shape shown in section, embedded in soft rubber, D, which distributes the transverse flexion over the sides of the tyre. The walls E of the cover are of fabric, having isolated transverse threads only supported on each side by canvas in which the threads run diagonally; thus the walls are very thin. The unburstable inner tube F, with embedded threads, is a special feature, and it is

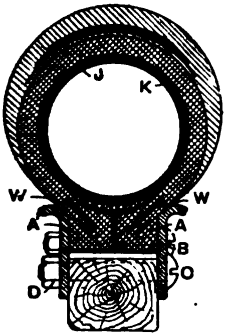


Fig. 496.

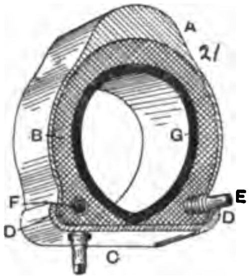


Fig. 497.

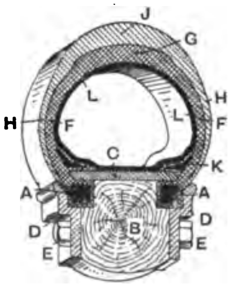


Fig. 498.

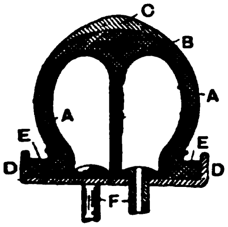


Fig. 500.

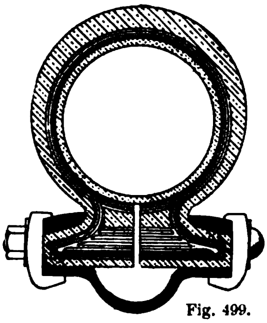


Fig. 499.

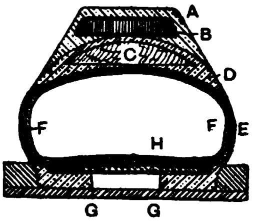


Fig. 501.

Fig. 496.—Goodyear Pneumatic Tyre. Fig. 497.—Collier Pneumatic Tyre. Fig. 498.—Toni Pneumatic Tyre. Fig. 499.—Fisk Pneumatic Tyre. Fig. 500.—Jackson Duplicate Tyre. Fig. 501.—Rucker Pneumatic Tyre.

compelled to take the shape shown, by the peculiar construction of the outer cover. Rectangular, hard rubber beads, G, are secured to the edges of the cover and enable the tyre to be fixed in place; they are secured by a wide metal band, H, which is made to tighten on them, its ends sliding over one another.

All the pneumatic tyres yet described are of the double-tube order, but single-tube tyres are largely used, and four examples may be noted. The Martin single-tube tyre (Fig. 502) is so made that its interior is easily accessible for examination. The wooden felloe, A, has a serrated steel rim, B, and the horseshoe section cover C has a rubber tread, D, a central canvas material, E, and an inner rubber surface, F; its sides, C, fit over the felloe and are clamped in place by the aluminium alloy flanges G, which have inner serrated faces which combine with the serrations in felloe and rim to give a good grip on the tyre, and to form an air-tight joint. Bolts H pass through flanges, tyre, and felloe. Wood and metal surfaces in contact with the tyre are coated with a preparation to prevent chemical action on the rubber; veloril now is in use for that purpose. The valve J passes through felloe and steel rim, and is a rigid fixture, being no part of the actual tyre. The appearance of the whole is improved by making the felloe meet the flanges at K, so hiding the edges of the cover. The New York single-tube tyre (Fig. 503) has an outer rubber, A, in which layers of fabric, B, are embedded. C is the central air space. Into the metal piece D screws bolt E, through felloe F. At the base, G, the tyre expands and rests on metal rim, H, and against flanges, J, made detachable by cross bolts, K. The Diamond is a single-tube pneumatic tyre (Fig. 504) popular in America; it is strengthened with fabric, A, fits into a semicircular rim, B, and is secured by the rim C. The Penna tyre (Fig. 505) resembles the Diamond; nominally a single-tube tyre, it actually is a double tube, the layers of rubber, A, being separated by a layer of fabric, B.

The plating of pneumatic tyres, done by placing on them metal segments which replace, and are supposed to be more effective than, the rubber on the ordinary outer cover, is condemned by de Mauni, who considers that the protective cover should be left as pliant as possible.

The Sampson protected pneumatic double-tube tyre (Fig. 506) has a leather belt, A, secured by copper rivets, B, whose expanded ends are prevented from injuring the canvas fabric, C, by the leather, D, beneath the outer rubber, E. Between E and the rim F is a slight protective thickness of leather, G. H shows the inner tube.

The Chameroy armoured pneumatic tyre (Fig. 507) has metal bands, A, fixed by rivets whose ends are kept from chafing the inner tube, B, by a layer of suitable material, C. Detachable steel pieces, D, fit over the bands, A ; they require to be sprung into place.

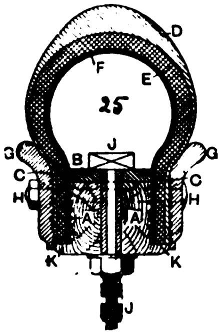


Fig. 502.

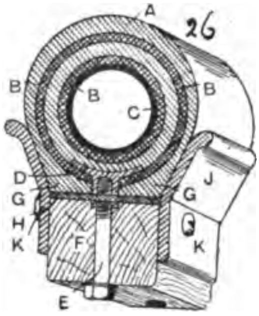


Fig. 503.

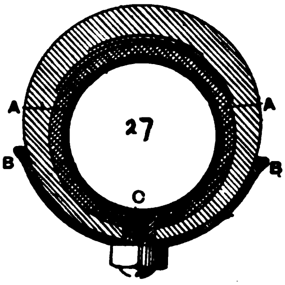
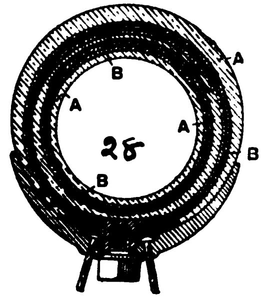


Fig. 504.



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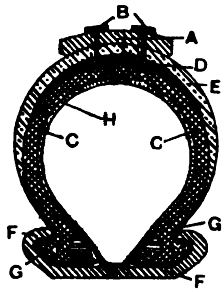


Fig. 506.

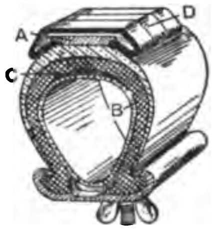


Fig. 507.

Fig. 502.—Martin Pneumatic Tyre. Fig. 503.—New York Pneumatic Tyre. Fig. 504.—Diamond Pneumatic Tyre. Fig. 505.—Penna Pneumatic Tyre. Fig. 506.—Sampson Protected Tyre. Fig. 507.—Chameroy Armoured Tyre.

Air pressures for pneumatic tyres cannot be stipulated with any certainty, but the minimum should be as follows:—For light cars with tyres of 65 mm. to 85 mm. (2·56 in. to 3·34 in.) section and with axle loads of 100 kg. to 272 kg. (220 lb. to 600 lb.), the pressure should be from 2·25 kg. to 2·8 kg. per cm.^{2} (32 lb. to 40 lb. per sq. in.); for heavier cars with the same size tyres, but with axle loads of 164 kg. to 204 kg. (450 lb. to 900 lb.), the pressure should be from 2·8 kg.

to 3·9 kg. per cm.^{2} (40 lb. to 56 lb. per sq. in.); and for the heaviest cars, with tyres from 65 mm. to 120 mm. (2·56 in. to 4·72 in.) in section and axle loads of 318 kg. to 907 kg. (700 lb. to 2,000 lb.), the pressure may range from 3·9 kg. to 7·8 kg. per cm.^{2} (56 lb. to 112 per sq. in.).

Of side-slip preventers, other than shaped or studded tyre treads, the Williams and the Parsons inventions may be briefly noted. The Williams arrangement is to let down into engagement with the road a pair of sharp-edged disc wheels. The Parsons device comprises two hoops fastened, one each side, against the edges of the wheel rims; one hoop is endless and the other has a coupling for adjustment. Fine mesh chain is threaded zigzag-wise over the tyre (*see* Fig. 508) from one hoop to the other. The chain must be slack so as to move relatively with the tyre (the hoops are found to move round slightly more slowly than the wheels), so that the chains do not continue to press on the same part of the tyre. This device has proved to be an absolute preventive of sideslip, and the wear and tear and the tendency to diminish speed consequent upon the use of such a device are stated to be only slight.

The elasticity of the wheels just treated is all outside the rim of the wheels, though endeavours have been made to have it inside. In an American wheel, probably reserved for the bicycle, each spoke was a steel foil with its point hinged to the felloe; the felloe had a series of hinges by which it could be bent and placed flat on the ground. De Mauni has manufactured several wheels of this type since 1875, though they have not been adapted for modern automobiles. The difficulties of construction are very great, and their flexibility causes injurious lateral displacements of their centre of gravity.

A spring wheel was exhibited by Roussel-Lecomte at the Paris Salon, 1902. It has neither spokes nor guides, but flat springs connect the rim to the hub and are bent so as to pass from hub to felloe and back again. They alone support the car and give flexibility to the wheel. The rim is connected by spiral springs with a disc fixed to the hub and lying on the inner side of the wheel; they are placed tangentially and take the drive. The tyre is solid rubber, These wheels have had a practical test on a Gardner-Serpollet car, but the result is not known.

Other inventors have placed the elasticity in the nave itself;

Ballin inserts indiarubber washers between the axle box and the top part of the nave. In another system, a metal piece is in the centre of the wheel; exteriorly this metal piece is star-shaped and is covered exactly by a regular indiarubber tyre; the wheel strictly so called is mounted on the nave thus constituted. The spokes are metal with a cruciform section, and the rim is composed of a wooden centre between two metal parts, the spokes of the wheels being fixed to one and the other rolling on the ground. Béguin constructs an ingenious wheel of metal, and in various parts of it places pieces of indiarubber; in particular there is a sleeve around the nave box between the discs which secure the spokes, and sheaths in the V which the spokes form in their junction with the nave. However, in most of these wheels the surface of contact does not elongate under pressure, but vibrations merely decrease, so that for several of them a pneumatic tyre is employed to lessen the traction strain. Hitherto it has been impossible to construct wheels which could decrease resistance to rolling without employing elastic tyres.

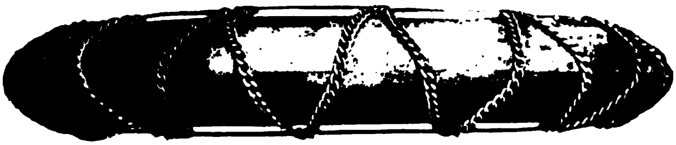


Fig. 508.—Tyre with Parsons Side-slip Preventer.

CHAPTER XIV.

SPRINGS, FRAMES, AND BODIES.

THE springs by which the underframe of an automobile rests on the axles must fulfil three conditions. They must afford a sufficient resistance and elasticity to support their load without their shape being altered permanently, their flexibility must deaden the effect of jolts on the car and passengers, and they must decrease the resistance to rolling. It is evident that by preventing everything above them from having to jump at each jolt, springs decrease the loss of kinetic energy due to inequalities of the road. The quality of the steel of which it is made is a great factor in the value of a spring; the finest variety is selected, and it is hardened and tempered in a very delicate manner; indeed, all the operations in the manufacture of springs always have to be entrusted to specialists. Steel should not be used unless it gives without permanent deformation an elongation of 7 per 1,000, and in calculating the resistance of a spring the plate which works most is not to undergo an elongation of more than 5 per 1,000. The plates, varying in thickness from 5 mm. to 10 mm. (·196 in. to ·393 in.), and in length from 0·8 m. to 1·1 m. (31·5 in. to 43·3 in.) for the main blade of ordinary springs, are centred according to cylindric surfaces of suitable profile. The curve radii decrease from the main blade to the smallest. If the elongation and the strain are to remain the same in all the blades their thickness also must decrease gradually, a condition aimed at in practice. To compare the flexibility of several springs a unit of pressure is taken, 100 kg. (220 lb.), for example, the decrease of flexion they undergo under this pressure being measured. Within the weight limits of modern automobiles this decrease per unit may be taken as constant for a same spring, and consequently the flexion of this spring is proportional to the pressure.

The chief types of springs are five in number. First, the straight springs have rolls above, as in Fig. 509, and rolls below when the springs are made to curve in the opposite direction, and opposite when one roll is above and the other below. These rolls usually are formed by coiling the ends of the chief blades. Rarely these ends, or one of them, are left straight, so that they can be inserted in slides made in the underframe of the carriage; in that case these springs are called slide springs. As a rule they are formed of five blades though for heavy vehicles there may be as many as eight (*see* Fig. 510). These straight springs are very suitable for heavy loads.

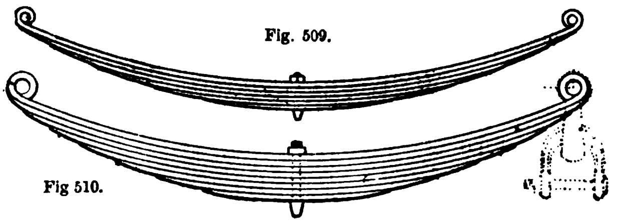


Fig. 509.—Straight Spring with Rolls. Fig. 510.—Straight Spring with Eight Blades.

The second kind is the nipper spring, composed of straight, opposite springs hinged together; according to the form of their joints these springs have hinges or loops, or sometimes a crook.

The third kind is the half-nipper springs, the top part of which, as compared with the preceding, consists simply of half a straight spring.

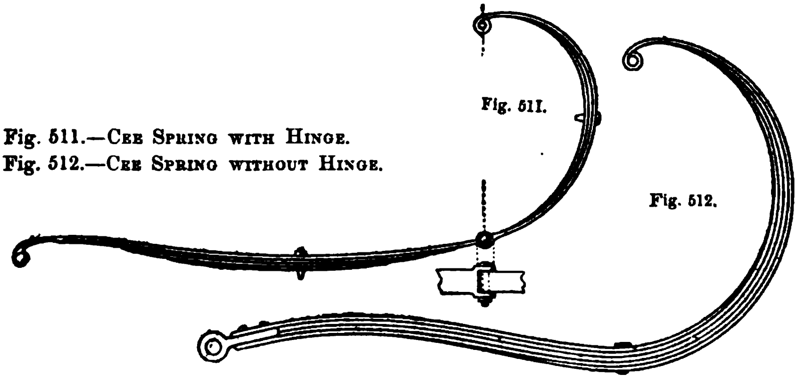


Fig. 511.—Cee Spring with Hinge.
Fig. 512.—Cee Spring without Hinge.

Cee springs, the fourth kind, are thus designated because they have the form of the letter C. The body of the car is supported at the rear by leather braces suspended to the end of the Cee spring. They deaden shocks in the longtitudinal direction as well as vertically. They have a good appearance, but are very expensive, and consequently are reserved for the most fashionable carriages and certain voiturettes; the Darracq electric coupé, the Augé, and the Lepape cars have these springs. Fig. 511 represents a Cee spring with hinge, and Fig. 512 a Cee spring without hinge, in which the exterior blades run from one end to the other; both of these are made by Bail and Pozzi. Fig. 513 is a Hannoyer Cee spring which has been adopted for the Darracq coupé. The leather brace winds on a piece of toothed iron. Sometimes the nipper and Cee springs are combined, as in the Bail and Pozzi type (Fig. 514).

Spiral springs form the fifth kind. These are coiled springs, quite different in form to the preceding. Fig. 515 represents one of the types made by the Compagnie des Hauts-fourneaux. They support considerable loads, and some of them are flattened only under a pressure of eight tons, though they weigh only 16 kg. (35·2 lb.); consequently they are often employed for heavy vehicles.

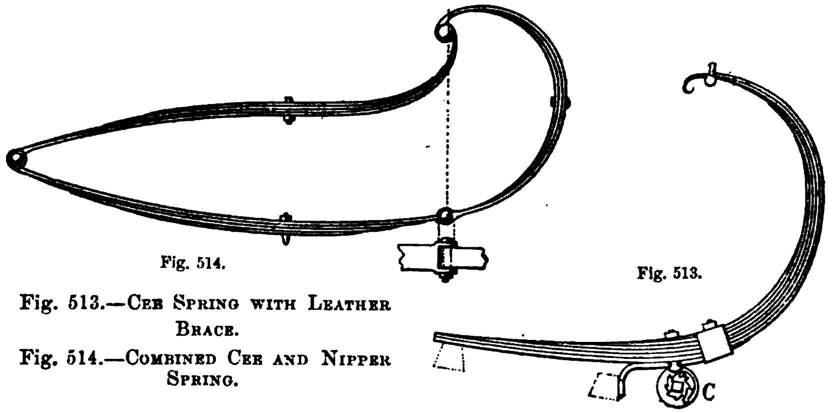


Fig. 513.—Cee Spring with Leather Brace.

Fig. 514.—Combined Cee and Nipper Spring.

The suspension implies the number of springs by means of which the axles support the main frame with motor, transmission gear, and the body. In the most common system the frame is suspended above the axles, the body being rigidly fixed to it; then the transmission gear (chains or longitudinal shaft) must have sufficient pliancy to allow the motor to follow the relative displacements of the axles when the flexion of the springs changes. This system protects the motor against jolts, though the passengers are affected by the vibration. In a second system the frame rests on the axles without springs, and then the transmission between motor and axle can be rigid and the body is suspended above; thus it is free from motor vibrations, though the motor suffers from jolts. In a third system the frame is suspended above the axles with the motor and transmission, which are always interdependent with it, and the body is suspended above the frame; thus both motor and passengers are not subjected to the effect of vibrations.

Double suspension evidently is good but complicates the car. With it the transmission must be pliant, although when the frame is suspended only in front a rigid transmission can be employed in the rear. The object of the suspension is to prevent inertia of the car and to intervene when the car is in collision with an obstacle. To do this it must allow the vehicle to rock in all directions — vertically, longitudinally, and transversally. But when chains are employed for transmission transversal vibration must not be too much, or the wheels gearing with the chains will have to be furnished with cheeks. Nipper springs allow vertical displacements, not much longitudinal displacement, and hardly any transversal displacement. When the car has a pivoted fore-carriage these springs are suitable only when they are light; on this condition only can they maintain the crown of this fore-carriage in a plane. Springs with a single blade favour transversal vibrations because the blade twists. In order to permit the variations which result from this torsion in the horizonal spacing of the two extremities of the blade, side-pieces are employed uniting each of its ends to a metal piece forming one with the frame. Sometimes the extremities of the springs are joined on both of the sides by a transversal blade, which in its centre supports the frame. In transmitting motion from springs to the body and non-driving axle, the blades of the springs must work by extension. For this condition to be fulfilled when the driving wheels are in the rear, which is usually the case, the rear blade of the spring fixed to the motor axle must be attached to the frame by rolls, whilst the front blade is fixed to the fore axle. The side pieces must likewise be placed at the front extremity of the rear spring and the rear extremity of the front spring.

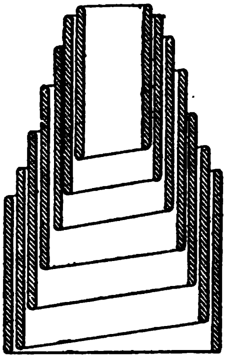


Fig. 515.—Spiral Spring.

Forestier considers that when pneumatic tyres are employed for vehicles weighing one ton per axle, the wheel journals or their pivots may be fixed direct to the frame, between which and the body transversal springs may be inserted; then transmission from motor to wheels would be much easier owing to their interdependence.

Pozzy recommends that in light cars the front springs should deflect from 21·3 mm. to 24·4 mm. per 100 kg. (·43 in. to ·49 in. per cwt.), and the back springs from 24·4 mm. to 29·2 mm. per 100 kg. (·49 to ·59 in. per cwt.). In heavy cars the deflections should be respectively from 19·3 mm. to 21·3 mm. and from 22·3 to 27·2 mm. per 100 kg. (from ·39 in. to ·43 in. and from ·45 in. to ·55 in. per cwt.). In heavy waggons the deflection should be from 9·4 mm. to 11·9 mm. per 100 kg. (·19 in. to ·24 in. per cwt.) at both back and front.

Simple suspensions are about the same as those of ordinary horse-drawn carriages. There are four nipper springs for light cars; rather heavy cars, such as delivery cars and omnibuses, often have five springs—two nippers in the front and three straight springs in the rear. The rear springs can be fixed under an iron cross-piece moved lengthwise by aid of a regulating screw to compensate for elongation of chains, though it seems more suitable to adapt the chain instead. Sometimes, as in the Compagnie Générale des Automobiles 1898 car, the rear springs are straight with a clip at the fore end and a worm rod at the rear to regulate the length of the chains. The springs with inverted clips were employed on a Jeantaud petrol car in 1894.

A device for suspending the fore-carriage has been patented by Jeantaud, and it is shown by Figs. 516 to 518. It consists of two springs *f f* placed parallel with the fore-axle *b* at a sufficient distance to form a supporting parallelogram, the two long sides of which are not deformed. The springs are joined to the axle by irons *c c* quite close to the point where the axle rests on the wheels, so as to reduce the projection; the clips leave the springs all their elasticity, but do not allow lateral displacements in spite of the absence of guides. The body of the car *e* rests on the centre of the springs *f f* by means of supports around whose axes it can rock.

Double suspensions may now be noticed. In some cars of the Compagnie Générale des Automobiles—who now seem, however, to have abandoned the device—the frame supported above the axles in the ordinary manner supports the body by means of other springs. It is the same in the Lepape car, in which the body is supported by the underframe generally with Cee springs. The motor is placed in front of the underframe. In the Jeantaud petrol car, above referred to, there is a transversal spring with inverted clips placed directly above the rear axle and supported by it; this spring supports the rear and main part of the weight of the motor and transmission gear. The very light fore-part is supported by a shaft, with a pinion at each end driving the motor wheels by endless chains. In this car, as in that about to be described, there is a toothed transmission from motor to axle.

In the Lanty, Hommen and Dumas delivery car, Figs. 519 and 520, the underframe C is supported above the fore axle by nipper springs R R, and above the rear axle by the rigid props B, which are fitted to the journals of this axle. The motor D has a shaft furnished with pulleys which drive by belts those on the intermediary shaft I. The latter turns in bearings supported by arms L, which form one with the props B, entraining by means of a pinion the toothed wheel of the differential mounted on the motor axle. All the system of the motor and the transmission may be said to pivot around the axle to follow it in the relative displacements it undergoes by flexion of the springs R R. The body is suspended above the underframe at the rear by springs M and in the front by spring N.

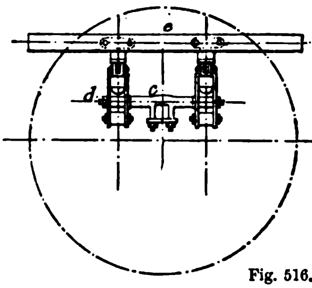


Fig. 516.

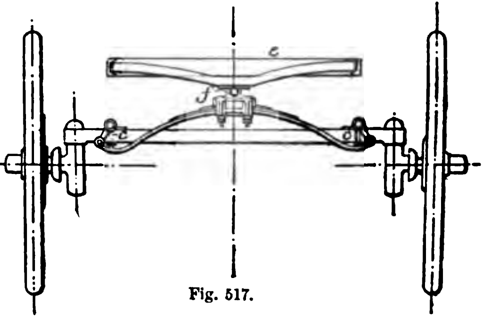


Fig. 517.

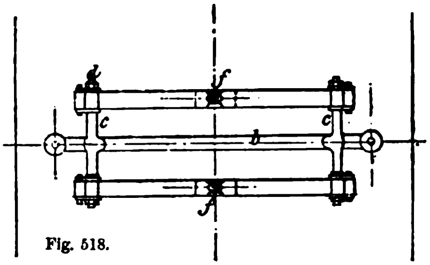
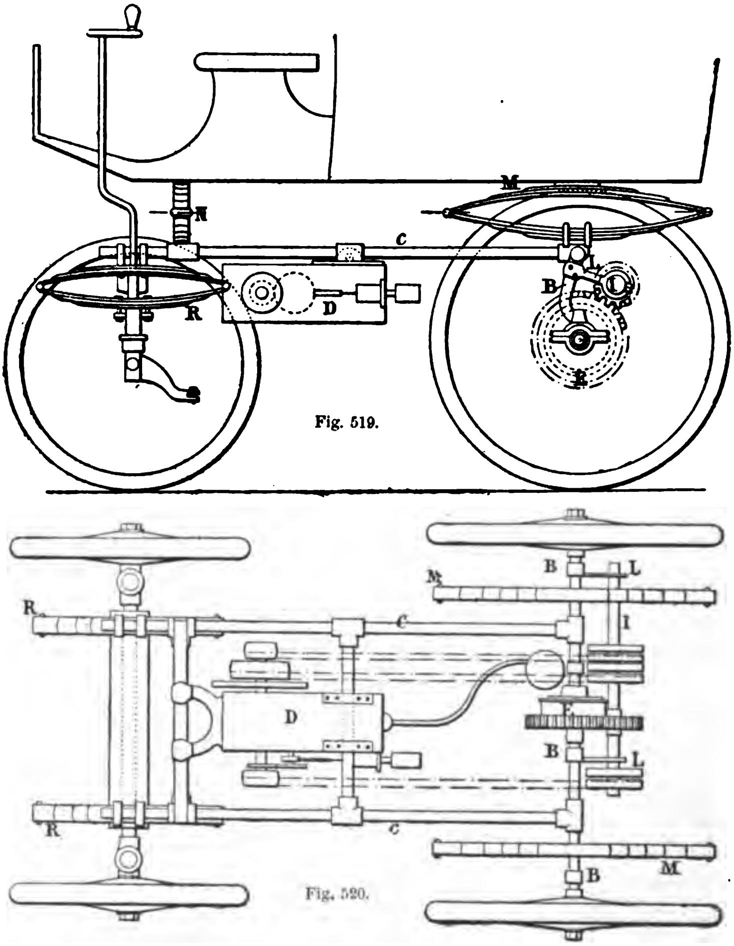


Fig. 518.

Figs. 516 to 518.—Jeantaud System of Suspension.

The main frames now will have attention. This frame rests upon the axles and supports motor, transmission gear, and body. Usually it is formed of two longitudinal bars united in front and rear by two cross-pieces and firmly intertied between the two. Originally—at least



Figs. 519 and 520.—Elevation and Plan of Lanty, Hommen and Dumas Suspension.

in the case of light cars—it was made of ash wood, but now steel is employed generally, usually in form of ⊏ or drawn out in tubes. In carriage building, thin channelled steel and tubes snap, owing to lack of judgment as regards their proper employment; the flat, round, or thick irons which have been and are employed have sections with very slight moments of inertia considering the weight. Tubes are lighter than these irons, but they must be brazed very skilfully. Profiled metal may be solid, and by its means the motor and transmission gear are fixed more conveniently. Sometimes the inside is lined with wood, which increases resistance without much extra weight. The intertying of the longitudinal bars must be particularly firm to prevent dislocation under the influence of vibrations and strains. To the static efforts are added the reactions of the parts in motion; consequently it is not prudent to rely upon the formula for resistance of materials to calculate the dimensions of the various pieces, and a big margin of safety must be left.

The Napier, Maudslay, Peugeot, English Daimler, Thornycroft, Humber, and many other cars have an underframe, carried by the main frame, as described in Chapter XVIII., and this supports the motor and transmission gear. It may be made of any material found suitable for the main frame.

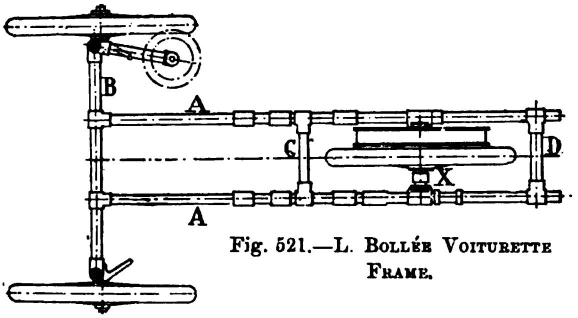


Fig. 521.—L. Bollée Voiturette Frame.

The main frame, whatever its material, must, as far as possible, be suitable for several interchangeable bodies without any other connections than some points of support furnished with indiarubber cushions. At first the frame was made rectilinear, probably because it favoured rigidity and interchanging, but it was not elegant. To give the body the appearance of descending between the axles, sometimes a step was placed between two mud-guards, the top frame comprised between the two being painted black. When both motor and driving wheels are in the rear, as in the old Peugeot and most of the Jeantaud cars, or in front, as in the Kriéger cars, disengaging can be obtained easily. When the motor is in front above the frame, and the driving wheels behind, as in most modern cars, it is necessary for disengaging to have inside the body a shut central corridor for the transmissions, but this is inconvenient. When the motor is under the frame, as in some of the Jeantaud cars, the axle of the transmission alone passes under the floor of the body.

Motor-cycle and voiturette main frames are tubular in nearly all cases, as in the Bollée voiturette, represented by Fig. 521, which consists of two side tubes A A, 38 mm. (1·49 in.) in diameter and 4 mm. (·157 in.) thick, united by three cross-pieces; the steering mechanism and wheels are fixed to the front cross-piece, and the intermediary transmission to the centre one. This frame weighs about 35 kg. (77 lb.) for a car weighing 210 kg. (462 lb.). In the oldest type of frame the side bars were reinforced near the centre by a stay and two rods; but now the side bars are thicker, and the stay and rods not used. However, tubular construction is not always employed; for instance, the Lombard mylorette and the Farman voiturette are exceptions, the latter having a profiled steel frame.

Many cars (including the Brooke, Toledo, Maudslay and Swift) have channel steel or tubular frames filled with ash wood, so producing constructions of great strength and flexibility. The Brooke channel frame is so made; in cross section each member measures 50·8 mm. (2 in.), but the metal is only 3·2 mm. (·125 in.) thick. The rectangular frame has the usual end cross members and two intermediate ones, and the design has been worked out so carefully that but few holes in the frame are necessary. The Brush car has a wooden frame strengthened with steel plates, so has the English Daimler; in the latter a pair of steel fish plates lie on the inner face of each side member. In front is a pair of cross angle pieces, another cross member serving to support the rear end of the change-speed gear. Suspended from the front angle pieces is a compact underframe which carries the motor. A great number of cars, again, have frames of channel steel only, no wood whatever being used.

An example of up-to-date tubular frame construction is found in the Humber car (*see* Figs. 522 and 523). Two main side tubes, A, are connected by four cross tubes, B, C, D, E. The two longitudinal tubes F pass from the front tube B to C and carry the motor. The tubes G, projecting downward from C and D, terminate in brazed-on steel bolts, and are stayed to each other and to the main frame by thinner tubes, H J, whose ends are connected by knuckle joints, and are held in place by bolts passing through them. The tubes forming the frame have malleable cast connecting brackets, which also provide attachments for the springs and steps. Tubes K L form a rectangular framework, the tubes K ending in sockets M, which fit over the bolts forming the ends of the vertical tubes G. Tubes L carry the change-speed gear. All the permanent joints are pinned and brazed.

The bodies of automobiles demand attention now. Before all else the body should be solid and as far as possible light and interchangeable. By fulfilling this last condition the development of automobilism is assured. It must be possible to employ an automobile in winter as well as in summer, and consequently there should be a suitable body for each season.

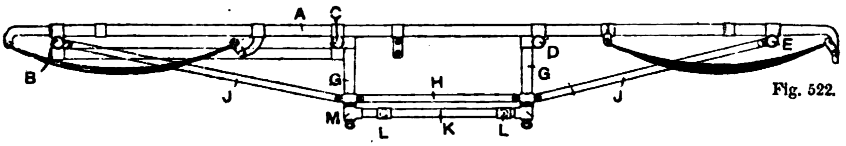


Fig. 522.

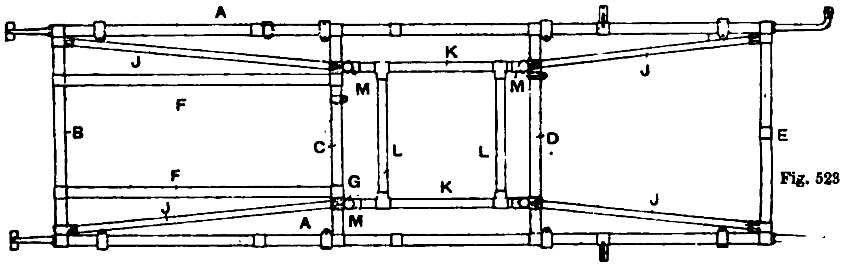


Fig. 523.

Figs. 522 and 523.—Humber Tubular Frame.

The efficient body must be the combined work of two specialists —the engineer and the carriage builder—and the best method of obtaining this is to clearly define their respective departments and give each perfect liberty therein. The flat frame, not having any connections with the body except as regards some points of support, is the best to assure this liberty.

Twelve types of body are illustrated on p. 485. Fig. 524 shows a spider or phaeton for one or two persons; this and the racing car, Fig. 525, have the simplest construction of any. The tonneau (Fig. 526) is exceedingly popular, and is known in many modifications, the closed tonneau (Fig. 527) and the tonneau de luxe (Fig.

528). The double phaeton (Fig. 529), closed phaeton (Fig. 530), and brake (Fig. 531) have roomy bodies, and the landaulet (Fig. 532), and the cab (Fig. 533) are ingenious designs in which the wheel base appears to be considerably longer than it actually is. The limousine (Fig. 534) is a smart vehicle, and the wagonette-omnibus (Fig. 535) is proving its usefulness more and more each year.

With regard to the carriage builder's work, some people maintain that the automobile, being a new vehicle, should have a new shape. Though there is some truth in this, it would be a mistake to abandon the present form of car, which is the result of accumulated studies and experiments. The carriage builder must adapt existing forms to the exigencies of the new kind of locomotion, and he can do so easily. Solidity and lightness are to be studied and can be obtained by employment of suitable materials, sheet iron or steel, aluminium and its alloys, and wood. One aluminium alloy—partinium in particular—is beginning to be largely used, and very light bodies have been made with it; a racing body for a Panhard 6 h.p. phaeton weighed only 22 kg. (48·4 lb.); and by its use in building a de Dion-Bouton twenty-seat omnibus there was a reduction in weight of 400 kg. (880 lb.) compared with the ordinary body. Partinium is an alloy of aluminium and tungsten. Rolled it gives a tractile strain of from 32 kg. to 37 kg. per mm.^{2} (20·3 tons to 23·49 tons per square inch), and an elongation of from 8 to 6 per cent., according to the proportion of tungsten. It is employed to make car bodies which, strength for strength, weigh about half as much as wooden bodies. There is difficulty in painting it, special skill being needed to prevent subsequent production, at the junction of the metal with the angle irons, of a greyish substance which causes swelling. Cast partinium has a tractile strength of from 12 kg. to 17 kg. per mm.^{2} (7·6 tons to 10·79 tons per square inch) and an elongation of from 12 to 6 per cent. It is employed for motor and gear cases even in cars of from 30 h.p. to 40 h.p. like the de Dion-Bouton.

A principle of far more importance with the new style of locomotion than with the old is to avoid large transversal surfaces which hinder the progress of the car. The problem perhaps will be solved by having bevelled glasses in front, these also conducing greatly to the comfort of the driver. These glasses are quite feasible, and should lessen the total air resistance met by the car, whilst they can be made to greatly improve the general appearance. Then, again, cars need

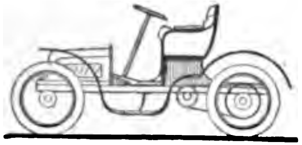


Fig. 524.—Spider or Phaeton.

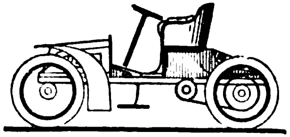


Fig. 525.—Racing Car.

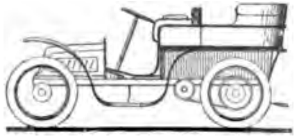


Fig. 526.—Tonneau.

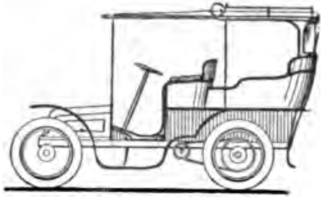


Fig. 527.—Closed Tonneau.

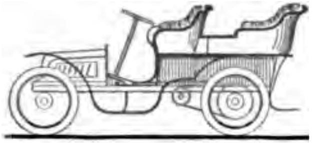


Fig. 528.—Tonneau de Luxe.

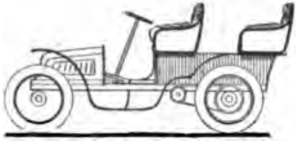


Fig. 529.—Double Phaeton.

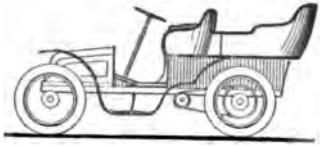


Fig. 530.—Closed Phaeton.

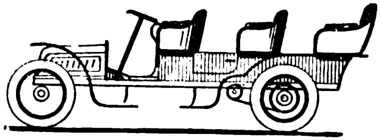


Fig. 531.—Brake.

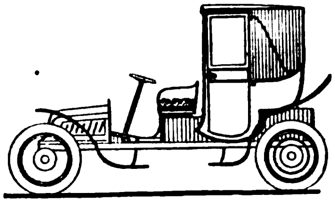


Fig. 532.—Landaulet.

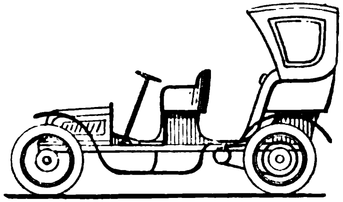


Fig. 533.—Cab.

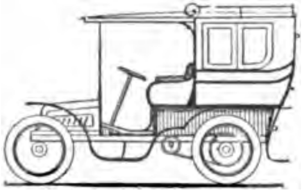


Fig. 534.—Limousine.

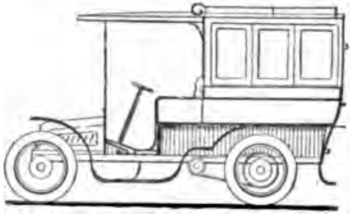


Fig. 535.—Wagonette-omnibus.

not be so ugly or so unsightly as sometimes they have been made. Until recently little care was bestowed upon carriage work, and there was little effort to enhance it by artistic trimming, etc. Now attention is being given to this question, and the good results already are apparent. Some cars of considerable bulk easily preserve their handsome appearance because the addition of the mechanism has little effect on the whole. The difficulty is greater with phaetons and other light cars owing to the largeness of the gear compared with the small bulk of the vehicle. With electric cars, in which the motor and gear are reduced to the strict minimum, the matter is easy. It was demonstrated quite a number of years ago that light electric cars can be made to be handsome. With petrol cars matters are much less convenient, and it is difficult either to beautify or mask the motor with its adjuncts (carburetter and cooler), the transmission gear, etc. Some persons consider that instead of endeavouring to hide the mechanism, on the contrary, its chief features should be brought into bold relief, as is done with railway locomotives; but a petrol motor is more complicated than a locomotive, and it is destitute of the simplicity that gives a machine beauty: also it is necessary to protect the gear against water and dust and to constantly lubricate it. There are some difficulties in the matter, but it is not thought impossible to overcome them.

CHAPTER XV.

BRAKES FOR AUTOMOBILES.

It is not necessary to demonstrate the absolute necessity of good brakes for cars. Cars in France must have two effective brakes, each of which is able automatically to stop or control the driving action of the motor. At least one of these systems must act directly on the wheels, or on pulleys forming one with them, and be able to instantaneously wedge the wheels; and one of these systems, or a special device, must prevent all backward movement. In the case of a vehicle with a bogey driving fore-carriage, one of the brake systems within reach of the driver must be able to act on the rear wheels of the vehicle. Each vehicle hauled must have an efficient and rapid system of brakes which can be worked either by the driver from his seat or by a special conductor.

Steam and electric motors easily can be made to give a braking instead of a propulsive effect. As regards petrol, when the governor prevents exhaust, the gases are compressed by the piston; and if the latter continues to form one with the transmission gear and car, there is produced a resisting strain which acts as a brake. Even when the exhaust works, the motor can act as brake; for example, in descending a gradient the wheels may move quicker than if they were driven by the motor only, and if the latter is in gear it produces a retarding effect, though this cannot replace the regulation brakes. In this chapter, only independent brakes will be considered. The brakes annul the kinetic energy of the car by transforming the energy into heat by the friction they produce on the wheels, tyres, or on pulleys forming one with the wheel or with one of the transmission shafts. Thus there are two classes of shoe brake.

In the first class the brakes act by bringing a shoe into contact with the tyre. Lagard proposed one based upon the plan of a scotching shoe similar to that employed in artillery waggons, and which has until late years been used to reduce the recoil of gun-carriages when firing. The shoes fall in front of the wheels, which continue to turn. The length of the cords or chains which unite the shoe to the vehicle is such that the wheels cannot pass over the shoes, but are fixed between the shoes and the road, in which position they skid. It is claimed that the tyres do not bear upon the ground and so are not worn; but, on the other hand, the road suffers from this skidding, and the car has to be given a slight backward movement before the wheels are released.

The contact of shoe and tyre nearly always is obtained by moving the first towards the second; but in the Bollée and Morrisse cars the shoe was fixed. In the Bollée car, by means of a single rear wheel which could be displaced, the transmission belt was stretched or loosened, and a pulley, forming one with the wheel, was brought to its extreme position forwards and into contact with the indiarubber shoe fixed to the frame. In the Morrisse cars, the rear driving axle, the bridge which supported it, and the springs could be moved around an axis of suspension by a lever. When they were forward, the motor was progressively thrown into gear and the car moved forward; when they were to the rear, the motor was thrown out of gear and the wheel tyres were applied against the shoes fixed to the car frame.

Briefly, the following is the device commonly employed for ordinary automobiles. When the brake shoe is movable it is brought into contact with the tyre by working a lever or screw along which can be moved a nut forming one with a rod which acts on the end of a lever; at the other extremity of the lever the shoe is attached. It is recommended to make the rod act by traction and not by compression. For metal tyres the shoe is made of cast iron, wood (twisted elm, boxwood, gaiac, has been proposed), or indiarubber. Cast iron lasts longest; indiarubber and wood give less noise and greater power without wearing the tyre; for indiarubber tyres the shoes are made of polished steel.

The inconveniences of shoe brakes acting on tyres are: (1) They are not instantaneous, especially the screw type, because several turns of the screw are needed to cause wedging; this, however, helps to preserve the car. (2) The shoes on the two wheels are not always applied with the same amount of force, and when the road is slippery this may cause the car to swing round. De Dion-Bouton propose a train of differential gear in the middle of the single shaft; rotation of this would cause wedging of the two shoes, but would be a great complication. (3) They wear the tyre considerably, especially when the wedged wheels skid along the ground, this very easily detaching solid tyres and shearing off the safety bolts of pneumatic tyres. Consequently, most wheels with indiarubber tyres do not have shoes, these being particularly objectionable with pneumatic tyres.

The great advantages of shoe brakes are: (1) They act with a lever arm as long as possible, it being equal to the radius of the wheel. (2) Therefore their mechanism is simple and reliable. (3) In descents they give a gradual wedging, which may be continuous, without demanding any work from the driver. (4) When ascending gradients they prevent the car from moving backwards. In a word, they are brakes for regulating speed, rather than for instantaneous stopping.

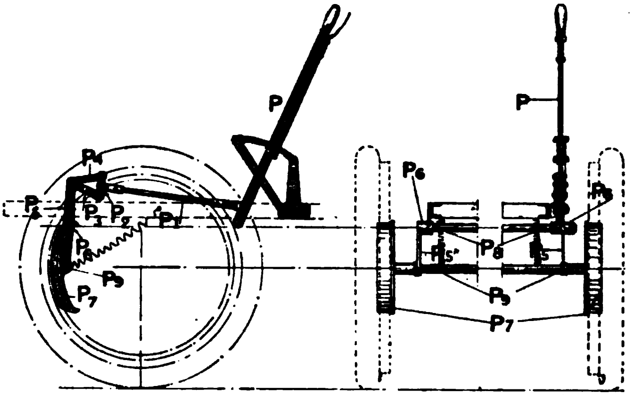


Fig. 536.—Wolseley Shoe Brake.

The second class is that of the brakes acting on pulleys. The arm of the lever which actuates them must not be shorter than for shoe brakes, as friction increases very rapidly with the angle of winding, and wedging is tight enough for instantaneous stoppage.

In the Wolseley shoe brake, blocks with large surfaces press against the inside of drums fixed to the rims of the rear wheels. The levers connecting the hand lever P (Fig. 536) with the leather-lined shoes P^7 are arranged to give equal pressure upon the two brakes. Lever P is pivoted to the frame, and is connected by rod P^1 to a swinging link P^2; the ends of this link carry the swinging levers P^3 P^4, the former being connected to the right-hand brake lever P^5, and the latter to rocking shaft P^6 and left-hand brake lever P^5. The two brake shoes are connected by a rod, P^9, from which the springs P^8 pass to the frame. The action of the hand lever P, in pulling rod

P^1, is to apply both of the brakes, and the swinging link P^2 connects it with both of them, and equalises the pressure exerted upon them.

The James and Brown shoe brake is shown in section and elevation by Fig. 537. Cast-iron shoes press against bronze or malleable iron. The wheel and the internal brake drum can be removed without disturbing the brake mechanism. In Fig. 537 A is the main axle, B the distance rod, C the sprocket wheel and brake drum, D the stationary member attached to the rear of the frame as shown in the detail X, and E is the lever operating the brake blocks F.

In cars with indiarubber tyres, where the shoe is not suitable, a band brake is generally placed on the differential shaft and a band brake on each of the driving wheels. These brakes are worked by pedals at least one of which, previous to bringing the brake into operation, withdraws the clutch, and so disconnects the motor from the transmission gear.

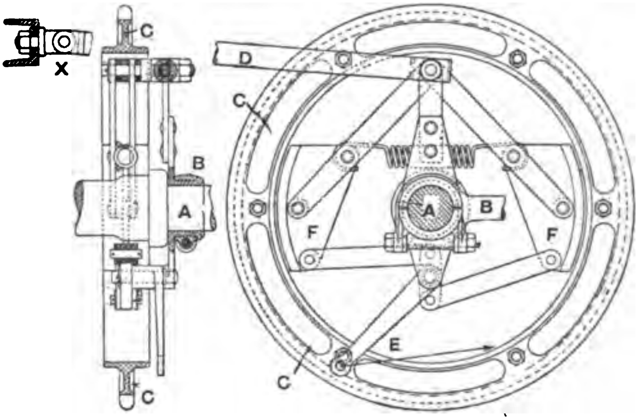


Fig. 537.—James and Brown Shoe Brake.

With brakes using bands, contact of band and pulley usually is over only three-quarters of the circumference. The steel band may be covered with leather or camel-hair, studded with wooden pegs to augment adherence by aid of a lever. Generally one end of the band is attached to a fixed pivot around which rocks a lever, whose one end is hinged to the other end of the band, and the second end to a traction bar worked by the driver. The band is brought against the pulley, and rotation of the wheel tends to tighten it and hasten wedging. Usually the pulley is mounted on one of the secondary transmission shafts, or on the naves of the road wheels, and that invented by Cloos and Schmaltzer is applied to a toothed wheel inside the nave, thus being concealed and protected from dust, mud, and grease, which in other systems sometimes cause the brakes not to work; but this is difficult to construct and to inspect, and it is not so powerful as the ordinary pulley brake. It is suitable only for light pleasure carriages.

As an example of a double-acting countershaft brake, the Wolseley

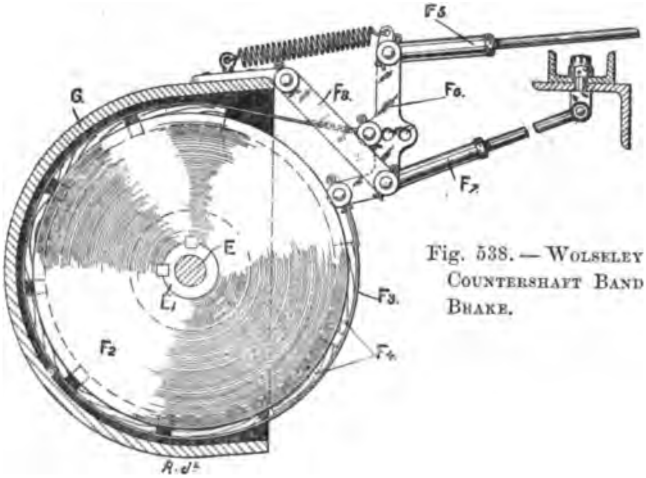


Fig. 538.—Wolseley Countershaft Band Brake.

(Fig. 538) may be noted. The differential sleeve E^1 carries the brake drum F^2, and is free to revolve about the countershaft E. The brake blocks F^4 are fixed to the band F^3, whose ends are carried by the bell-crank F^6. The bell-crank is carried by an adjustable distance rod, F^7, passing to a cross member of the main frame, and by a swinging link, F , whose other end is connected to the aluminium gear case G. A spiral spring also connects the gear case with the piece F^6, and this tends to hold the brake in its "off" position. The adjustable rod F passes to a pedal which operates the brake. To compensate for stretch in the brake band F^3 three separate adjustment holes are drilled in the bell-crank F^6.

The Brooke device for equalising the pull of the brakes on the rear hubs employs a transverse rocking shaft to which the brake lever is attached, as are also the double-acting band brakes. The ends of the brakes are not fixed in the usual manner, but are connected to horizontal bell-cranks pivoted to the rear corners of the frame. The free ends of the bell-cranks are connected together by an adjustable rod across and behind a frame, and a running joint with right and left hand threads permits of an easy tension adjustment of both brakes, the connecting rod always equalising the pull of both brakes.

Band brakes have to be provided with means of holding the band from the drum at those times when the brake is "off." In the Humber rear wheel compensated, double-acting band brake, the following arrangement is adopted. In Fig. 539 A is the section of the band to which is fixed a steel pin, B, which passes through the projecting arm C of the malleable casting D. The spring E normally holds the band clear of the brake drum F, but permits it to work when the brake is applied. There is a simple compensating action for the two side brakes; they are applied by a steel cord passing from one through a cross tube, over a pulley mounted on the hand brake lever, and thus to the other brake. Throwing forward the lever tightens the cord on both band brakes, and the freedom of the cord to slide in the direction of its length ensures an equal degree of tension on the two brakes. The construction of the Humber driving wheels and the manner of securing them to the axle are made clear in Fig. 539 also. G shows a portion of the shafts, which comprise the divided rear axle. H shows a steel tube surrounding the axle; it contains at the ends brass bushes and lubricators.

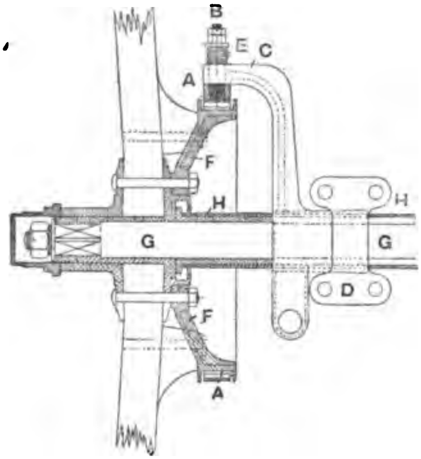


Fig. 539.—Humber Band Brake.

The Prescott steam car (American) has bicycle-built wheels, and the hubs of the rear wheels serve as the drums of interconnected band brakes, the bands operating between the two sets of wire spokes.

In the Renault brake (Fig. 540) the steel band, having inside a camelhair belt, is coiled one-and-two-third times around the steel drum; the band is illustrated by Fig. 541, in which the points marked *a f* are the same as B and C in Fig. 540. Chains B A, C A, unite the ends of the band to point A, which forms one with the axle S, all the locking stress being brought to bear upon A; the rods B D, C E, connect the same ends of the band to the little rods J D, K E. All these parts exist on both of the sides of the underframe. Rods J D, K E, are united with similar ones by the flat iron bars D E, the centres of which are united by powerful springs F G to a collar surrounding the axle. These springs draw the rods

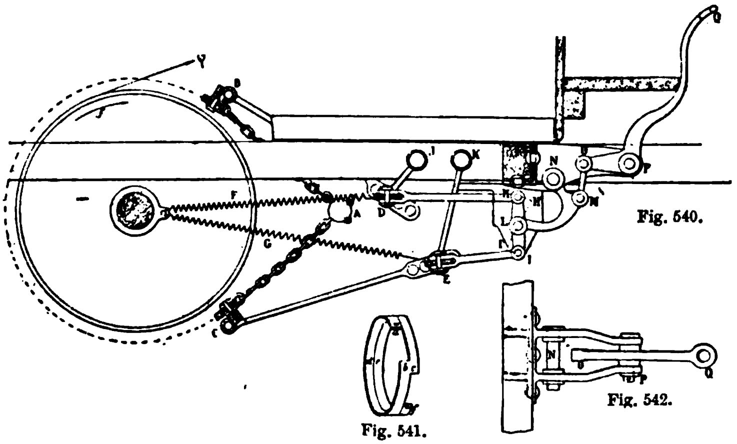


Fig. 540.

Fig. 541.

Fig. 542.

Fig. 540.—Renault Brake. Fig. 541.—Band of Renault Brake.
Fig. 542.—Plan of Brake Pedal.

B D, C E, towards the rear, and thus remove to a distance the drum bands, which then do not exert friction strain upon the drums when the brake has not to be locked. To bring them near the drums the pedal Q (*see* also plan, Fig. 542) is pressed. By working the levers shown the bands are pressed on the drums, and locking is produced. If the car is advancing, the wheels turn as indicated by the arrows *f*, and a component of friction is developed between the blades and drums such as Q, the chain B A stretches, lever H I assumes the position H^1 I^1, chain C A tightens, and the locking strain is produced at A. Inversely, when the car is retreating, chain C A stretches and chain B A tightens, always bringing the locking strain on point A. Thus the brake locks automatically in the required direction. Fig. 542 is a plan of the pedal and adjoining parts.

The Hautier old brake is shown by Fig. 543. The ends of the winding bands are fixed to two bars, A H, B G. When the lever *b c* is pulled so that the end *b* comes forward, the various parts move as indicated by the arrows, and the bars are applied against the fore edges of their slides; H acts as point of support and the brake locks for forward motion. It locks for back motion when end *c* of the lever *b c* is brought to the front.

A pedal band brake on the countershaft, and a hand band brake on each of the rear driving wheels, is the most usual practice; but an improvement on the hand side brakes is an inside expanding brake acting on the inside of a special sprocket ring.

Band brakes have such obvious advantages that they are almost necessary adjuncts of an automobile; but they also have their inconveniences. Pressure must be exerted on the pedal during all the time they are acting unless, as in the Landry-Beyroux cars, the brake is tightened by a special device. The heating caused by friction of the cleats against the pulley under the effect of prolonged tightening might cause ignition of the wood. Metal cleats last longer and cause less severe friction.

In rope brakes the winding may be in any number of coils; thus the power may be said to be limitless, and the action nearly instantaneous. The almost universal type of this brake is the well-known Lemoine brake, which, on the Paris 'buses, both tightens the rope on a hopp of the nave and applies the shoes to the tyres. This would have two inconveniences for automobiles: it would wedge the wheels and produce flat places on the tyres, owing to their friction with the ground, and it would wear the tyre by pressure of the shoe. Consequently it has been altered, so as to be regulatable, and shoes are discarded. Instead of the conical hempen rope studded with wooden cleats, which varied in length with the temperature and wore out quickly, use is made of a flat, pliant rope made of a number of steel wires, studded with cleats of wood, leather, copper or iron.

Rope brakes tighten only in forward motion of the car, backward motion breaking all connection between rope and pulley. Thus the coiled brake is eminently an intermittent and instantaneous brake, just the opposite to the shoe brake; the two systems then, very happily, complete each other. Consequently they are usually found associated with metal tyres in motor cars, and often enough conjugated, as in the Weidknecht omnibus, where they can be worked together or separately. Coiled brakes can be made to work in both directions.

The Jeantaud rope brake (Figs. 544 to 546), for instance, is double-acting. Two ropes are wound in opposite directions so as to correspond respectively to forward and backward motion of the car. One end of the ropes is fixed rigidly to the axle E of the car and on the other to two chapes, O and P, mounted on an axle, X, which can pivot in support A fixed upon the suspension spring. The rope C^1, starting from the fastening piece S, winds from right to left. When the brake is to be applied whilst the car is moving forwards, the lever is brought from D to D^1; the latter entrains axle and chapes O P; then P brings the cleats on rope C^1 against the drum, which rotates and completes the locking. If the car is running backwards the same motion of the lever tightens the cleats of rope C.

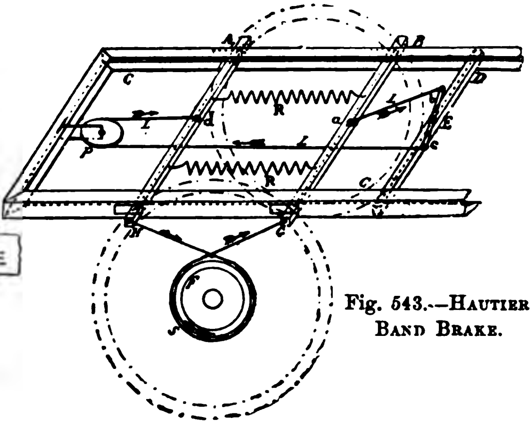


Fig. 543.—Hautier Band Brake.

Fig. 544.

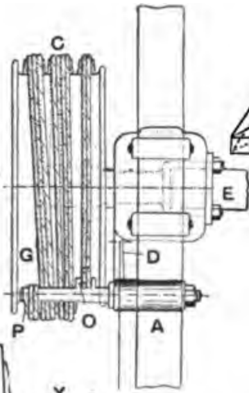
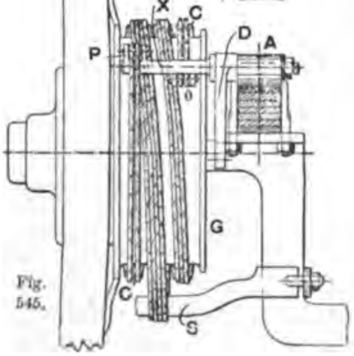


Fig. 545.



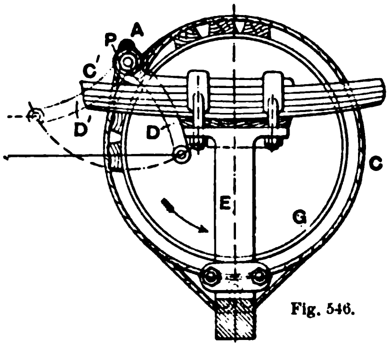


Fig. 546.

Figs. 544 to 546.—Elevations and Plan of Jeantaud Brake.

In the Darracq brake a square shaft carries, immediately it leaves the case of the change-speed gear, a metal drum or pulley, and against this are pressed two bronze discs commanded by a pedal placed to the right of the driver. This device is powerful, does not cause burning, and acts during both forward and backward motion. Fig. 547 gives an idea of its construction.

The Krebs old brake (Fig. 548) also is double-acting, but it does not work by winding; instead, there is simple application of its jaws, and it is mounted on a drum, which it completely surrounds. When the rod T is pulled in the direction of the arrow, the two jaws B C, hinged at *a* to a piece A forming one with the underframe, are pressed against the drum. As soon as traction ceases to act on rod T, the spring R, moves them away from it.

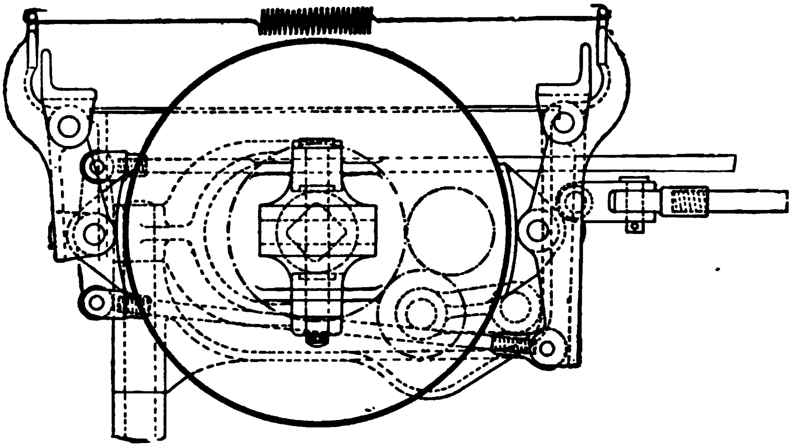


Fig. 547.—Darracq Brake.

The Chenard and Walcker combined brake and clutch is shown by Fig. 549. The fly-wheel A on the crank shaft has jaws, B, fitting into slots in the outer member C of the cone clutch, and thereby forming a flexible connection. C is mounted freely upon the end of the shaft D, which is connected by coupling E to the change-speed shaft F. The inner and sliding portion, G, of the clutch has two cone faces, one engaging with the clutch member C, and the other with a fixed cast-steel brake-ring, H, which is bolted to the longitudinal members of the underframe. The member G rides upon a square portion of shaft D, and normally is held in its forward position by helical spring J. Pedal K is pivoted at L, and operates the clutch through the adjustable stud M and lever N. The last named is pivoted on rod O, and its lower end is forked to engage with pins on the thrust collar P. The inner clutch member G does not come into contact with the brake-ring H until after it has been withdrawn from the other clutch member C. The pedal K can only disengage the clutch and cannot operate the brake. A pedal to the right of K is, however, connected with the clutch in such a manner as to give a further travel to the cone portion G.

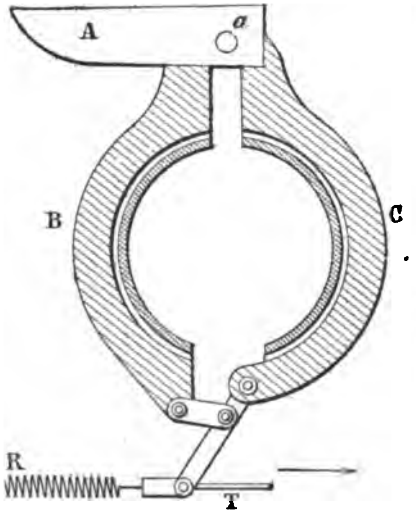


Fig. 548.—Krebs Double-acting Brake.

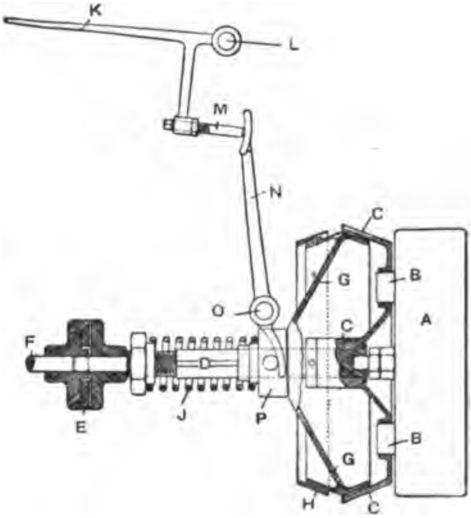


Fig. 549.—Chenard-Walcker Combined Brake and Clutch.

The chief brake in the Velox car is an actual part of the transmission gear, and there are the usual side brakes as well. In Fig. 550 A is the change-speed gear box, B the driving shaft leading from it, and C the propeller shaft whose elongation, D, drives the bevel gearing on the live axle differential. The shaft B carries the combined brake drum and cushion device (*see* Figs. 550 and 551). The actual brake drum E is keyed to shaft B, and contains another casting, F, rigid with the outer part of a flexible coupling. Bolts, G, hold the two together, but as they are fixed to one end to one part, and ride in slots, H, in the other part, they allow a slight relative rotary movement between the outer casting E and the inner casting F. To a great extent, though, relative movement is prevented by the action of internal helical springs J; but when the car starts from rest, or when the load on the motor is varied suddenly, these springs allow a slight relative movement between the two until the bolts G are forced to the ends of the slots H, when the two parts become rigid. The novel band brake is designed to take up any wear that may occur, but yet to ensure that the two parts of the metal band K do not rub normally against drum E. (Fig. 552 is a view of the brake band.) The two halves of the band K are pivoted about the fulcrum pin L, carried in casting M, which is pivoted at one end to one of the cross tubes of the main frame, passes round beneath the band, and terminates in the adjustable stop pin N. The point of this pin rests against the underside of the lower half band, and so allows the spiral spring O to separate the two parts of the band and hold them clear of the drum E. The operating pedal works a rod and bell-crank lever to pull rod P from right to left, and so causing link Q to tighten the band and to give a double-acting braking effect through the adjustable connecting pin R, between the two parts of the brake band. Of course, the friction faces are metal-to-metal.

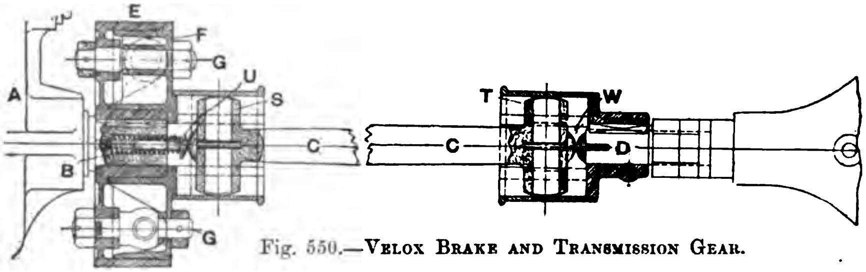


Fig. 550.—Velox Brake and Transmission Gear.

The Velox spring-cushion device may be referred to in connection with the above. At each end of the propeller shaft C, Fig. 550 (an elongation of this shaft drives the live axle differential through bevel gearing) is a flexible-coupling member, S T. The external portion of S is rigid with the casting F, and T is fixed to shaft D, upon whose other end is a small bevel wheel driving the differential. The shaft C can accommodate itself to any likely relative movements between the rear axle and the frame, and is free to move a certain distance in the direction of its length, though normally it is pressed rearward by a small spring-controlled plunger, U, whose rounded end is in contact with the similarly rounded end of shaft C. There is a similar construction, but minus the spring, at W. There is another flexible coupling between the clutch and change-speed gear box. The object of this arrangement is that when the car is started from rest the shock imposed on the gearing may be absorbed largely by springs, and its effect cushioned.

The pawl and devil-drag or sprag are two devices which may be used when a car has not a brake that will prevent backward motion. The pawl is brought by the driver at the required moment into contact with a ratchet wheel fixed on the nave of the driving wheel.

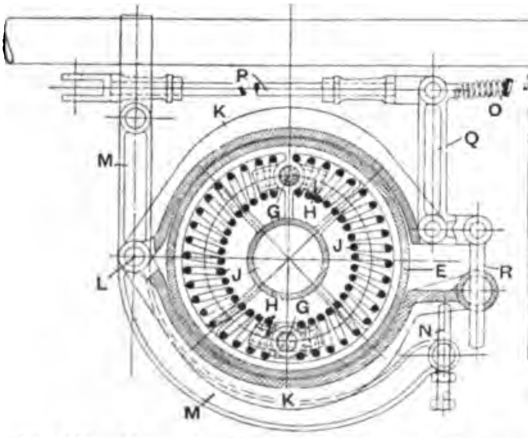


Fig. 551.—Velox Brake and Transmission Gear.

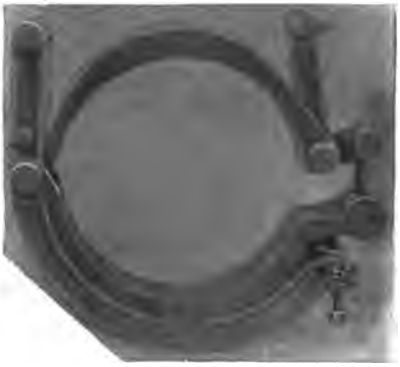


Fig. 552.—Velox Brake Band.

Sometimes the ratchet is placed on the differential box, though this is a bad arrangement, because if all the chains snapped the car would be deprived of all means of preventing backward movement. The sprag is allowed to trail behind the car when ascending a gradient, and by propping itself on the ground it prevents all retrograding. Baron A. de Rothschild invented a convenient device to drop and lift the drag. But it is easy to forget to use the pawl or drag, or these may be so rarely employed in level districts that, at the critical moment, the device by which they are released may refuse to act; and for these reasons the use of a band brake acting for both directions is strongly advised. The untrustworthiness of the sprag, owing to its doubling up or being over-ridden, has been abundantly proved of late.

CHAPTER XVI.

LUBRICATING DEVICES FOR AUTOMOBILES.

LUBRICATION is of the greatest importance in the operation of an automobile, but it is difficult because the parts requiring to be lubricated are mostly out of sight and reach when the automobile is on the road. The parts to be lubricated are numerous, and include the motor cylinders, distributing and regulating mechanism, reversing and speed-changing gear, differential, pinions and wheels, chains, bearings, and in general all the parts exposed to friction. The valve-rod thrust bearings, cups of the coupling plates, lever hinges, and steering gear must not be forgotten.

The lubricants employed are somewhat varied, as their viscosity depends on the pressures the pieces have to support and the manner in which the lubricants are brought into contact with the surfaces. Their boiling and igniting points must be at a temperature higher than that of the parts to be lubricated; this has special reference to petrol motor cylinders and to super-heated steam motors, because if the lubricant burns and decomposes it may cause the motor to wedge.

On the other hand, lubricants must not freeze in winter. A practical method of decreasing the freezing point of lubricating oil is to add to it a little petroleum, one part to ten, when the temperature is near freezing point, and a little more when the temperature is much lower. The lubricant should be as stable as possible, and this stability is connected closely with its chemical qualities—acidity, oxidability, etc. Consequently vegetable oils more or less siccative are not desirable. Mineral oils are more neutral than others and do not attack the metals they lubricate.

A perfect acquaintance on the part of the user with the qualities of the various lubricants would be very valuable, as it would enable the most suitable for each particular case to be selected. Superficial examination can enable a practical person to form an idea of the consistency of oil, but he cannot say whether the oil will be suitable at the various temperatures of the mechanism it is to lubricate. A. Chenevier, director of the laboratory of the Chemins de Fer du Midi, has invented an instrument by aid of which a diagram representing the degrees of fluidity can be constructed for an oil at various degrees of temperature to the maximum (200° C. or 392° F.) it has to undergo in a high-pressure steam cylinder, say of a railway locomotive. This, however, would be insufficient for petrol motors, and as the matter is so important it would be a good thing to test automobile lubricating oils as Chenevier did those employed for railway vehicles.

Melted tallow chiefly is employed for lubricating chains; a consistent grease for pinions, chain wheels and bearings; animal oil, as far as possible neat's-foot oil, for steam cylinders, and fluid oils for petrol motor cylinders, for which also mineral oils or oleonaphthas are much employed, as they boil only above 300° C. (572° F.). At the present time oleonaphthas are made which are most varied in aspect and properties, from fluid oils to consistent grease like tallow. They alone are employed for the motor cylinders, and they also can be used for distributing mechanism, toothed gear, and hinges.

The methods of applying lubricants vary. Chains are dipped into melted tallow and put into their places when the grease has cooled, though sometimes they are oiled while in position by aid of a brush or oil can. Bearings, bevel wheels, hinges, and parts having oil holes generally are fed with a can. Pinions, chain wheels, and exposed gear are coated with consistent grease by aid of a brush and sometimes with thick grease made hot. Patent wheel boxes have a small quantity of oil poured into them. The parts enclosed in gear cases (cranks, speed-changing gear, and differential) are lubricated automatically by simply working in oil, which merely requires to be replenished from time to time. These systems of lubrication are very effective, the last especially, and are exceedingly simple. Generally, inexperienced motorists lubricate the motor a great deal too much. To form an idea of what is necessary, it may be said that a 500 h.p. steam engine is lubricated sufficiently by one drop of oil per minute; whilst a petrol motor, like that for automobiles, must not have more than six to eight drops per minute. Excess of lubricant in a petrol motor cylinder is injurious, because it disturbs the composition of the carburetted mixture and deprives the explosion of part of its force.

The modes of lubricating deserving greater attention are those which, instead of supplying at one time sufficient lubricant to last for a more or less long period, supply it continuously and precisely as it is required. Lubricators of this type must be sure in spite of the vibrations of the car, variations of temperature, and the greater or less fluidity of the oil. They must not supply an excess, so that oil is spilled, and they must allow of being regulated independently of each other. It must be easy to stop and start them with the motor, or at least with the car, or, what is better, they must stop and start automatically with the motor and car. It is doubtful whether one apparatus possesses all these qualifications.

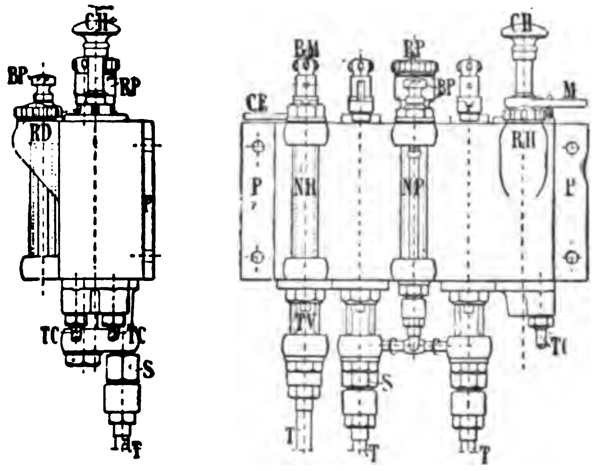


Fig. 553.—Hochgesand Oleopolymeter.

Lubricators can be divided into two chief classes, according as they are based upon the natural working of physical phenomena (gravity, condensation of steam, suction of pistons), or are worked mechanically.

Physical lubricators first will be described. Those with falling drops, as a rule, are not reliable, unless at each instant their working is observable by the fall of a drop of oil into a glass tube.

The Hochgesand oleopolymeter, shown by Fig. 553, is constituted by a bronze box 10 cm. × 5 cm. (3·9 in. × 1·9 in.), the width being varied according to the number of feeds required, so as to contain 150 g. (5·3 oz.) of oil per feed. Each of them is regulated separately by a rod with cone-shaped end resting on a milled nut by means of a hinged button. When this button is flat, feeding is stopped; and when raised the oil escapes in a quantity regulated by the position of the milled nut. When the rod is raised the oil flows copiously, so as to quickly fill the pipes at the time of starting. The milled nut is prolonged by a dipping tube, in which a spring supports the regulating rod. The air not being able to enter the box otherwise than by the space comprised between the regulating rod and the dipping tube, the flow of oil is maintained constant whatever the level of oil in the box. In fact, this flow depends solely upon the height comprised between the lower end of the tube and the end of the regulating rod. Each oil outlet has a light valve which prevents the oil being forced back.

The Holt automatic lubricator for cylinders (Fig. 554) is based on the play of a diaphragm, A; when the motor piston sucks the carburetted mixture the diaphragm rises, and the valve S allows a certain amount of oil to pass and run into the cylinder. Moreover, this amount always is the same, because the vessel communicates with the air by hole O, and the cylinder C is kept full by the liquid brought through tube T; when the diaphragm rises, the liquid falls into the cylinder by groove R.

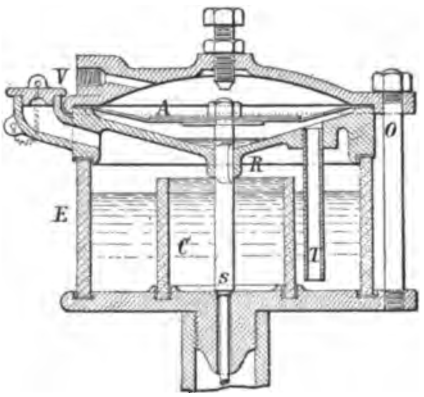


Fig. 554.—Holt Lubricator.

The Brunler continuous lubricator for cylinders works in the following way:—The hollow piston P (Fig. 555) has channels *a b*, in which is pipe *t*; by means of this pipe the oil or grease under pressure reaches the groove *r* covered by a perforated band of metal *p*: these perforations distribute oil over all the circumference of the piston. A current of water flows to the inside of the piston through the channels *a b*, and after having cooled it and the lubricant, it escapes through channel *d*. This lubricator is certainly combined so as to bring the oil to the points where needed; but perhaps obstruction of the tube is to be feared.

Of lubricators with rising drops, the Consolin apparatus is an instance. It is employed with steam, and is based upon condensation of the steam below the oil. Most physical lubricators have the inconvenience of not stopping with the motor, so that unless their working is interrupted the oil continues to flow uselessly.

The simplest of non-automatic mechanical lubricators is the hand-worked apparatus which is within reach of the driver, who works it from time to time during a journey. It is very reliable, and many good constructors employ it to lubricate the cylinder.

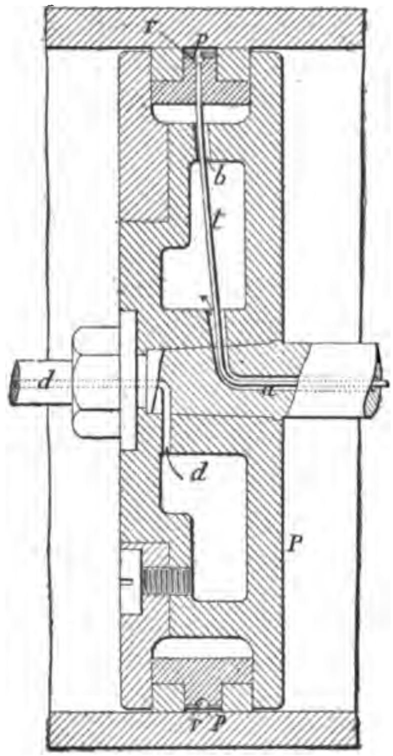


Fig. 556

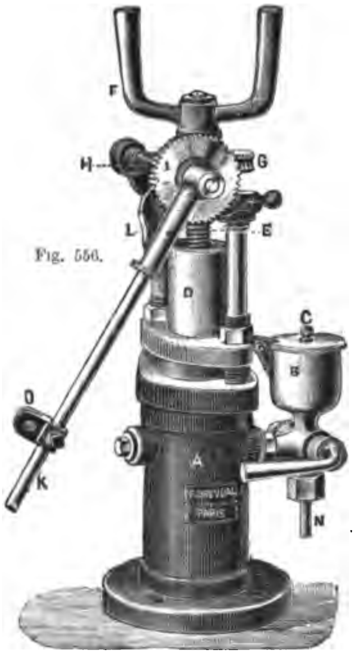


Fig. 555.—Brunler Lubricator.
Fig. 556.—Drevdal Terminus Lubricator.

Of automatic mechanical lubricators working by compression, the Mollerup lubricator is a type. It is employed for steam cylinders, but will not be described here, as it differs only slightly from the Terminus lubricator (*see* below), in which the pawl and ratchet, which wears very rapidly and makes a noise, are replaced by another device; the Terminus is preferred to it, because it is not so heavy, and more precisely regulated for the amount of oil to be fed.

The Drevdal Terminus lubricator is shown by Fig. 556. A is a cylinder filled with oil, in which moves piston D, mounted in a movable nut on the screw E; this screw turns under the action of the spiral gear wheel G, which is driven by an endless screw upon an extension of which the driving wheel I is keyed. This wheel, which occupies the place of the Mollerup ratchet, has a projecting cordon on each face, upon which the dog L bites. K is a rod forming the end of a chape mounted on the radius of the wheel; O is a slide piece connected with a little rod which receives slight motion (2 cm. to 3 cm; ·78 in. to 1·18 in.) from the machine. The oil driven away by fall of the piston is conveyed to the point to be lubricated by a small copper tube with a retaining valve to keep it full when the apparatus is at rest. The type holding 300 g. (10·58 oz.) of oil, used on the Scotte cars, enables a journey of 130 km. (80·7 miles) to be made without a new supply. For lighter cars an aluminium apparatus can be had to contain from 50 g. to 100 g. (1·76 oz. to 3·5 oz.).

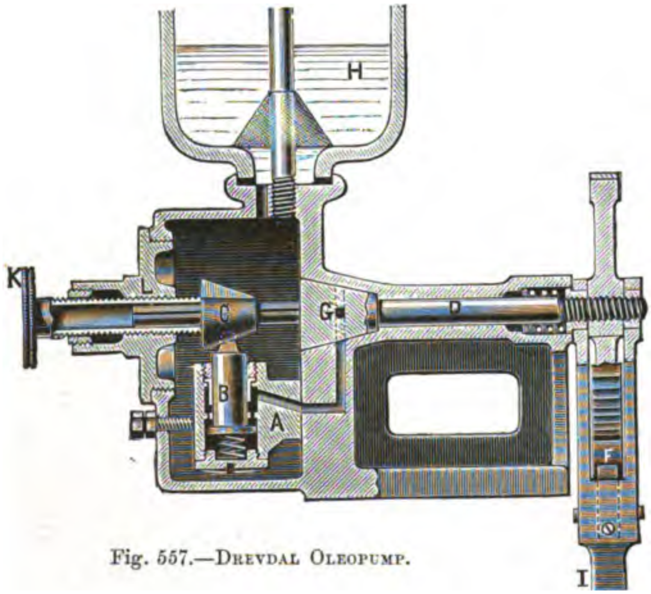


Fig. 557.—Drevdal Oleopump.

Some automatic mechanical lubricators work by suction and forcing. In this class are found first the pumps directly connected with a part of the machine without reduction of motion, a fact which limits their employment to machines of low rates of speed; secondly, some apparatus is rather more complicated.

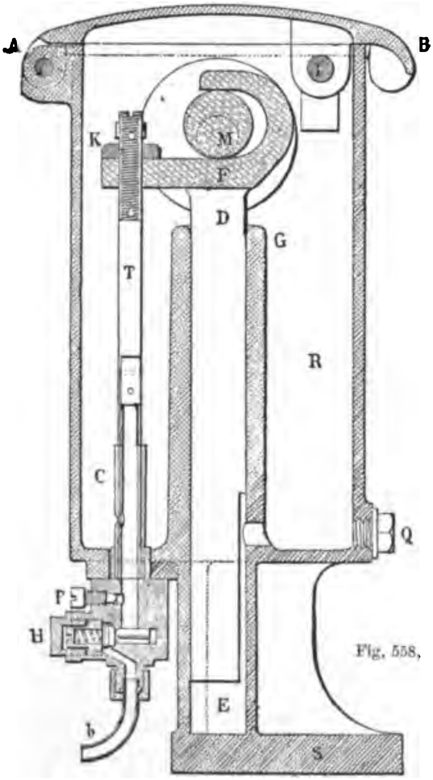
The Drevdal oleopump is shown by Fig. 557. In the pump barrel

A, kept full of oil by communication with the vessel H, there is a piston B, which descends under the action of the double cam C, mounted on the shaft D, and rises by the action of the spring to be seen below. This upward movement, which causes suction of the oil, takes place abruptly twice per revolution, and the descending motion, which forces, is almost continuous. The cone G acts as a slide valve, bringing the pump barrel alternately into communication with the oil tank and the oil distributing pipe. Shaft D is driven by a ratchet wheel under the action of the pawl F fixed on lever I, which is given a slight movement by the motor. The delivery is regulated by milled nut K. The oleopump is employed to lubricate petrol cylinders, and it can be constructed with several force pipes.

In the Bourdon multiple lubricator (Fig. 558) a shaft M passes through the top part of the receptacle R and is set in motion by a ratchet wheel, a pawl, and a lever not shown in Fig. 362, but resembling those of the Drevdal oleopump. Shaft M carries an eccentric, which is caught by the fork F, which thus receives a vertical alternating motion. On the lower branch of this fork as many pistons are screwed as there are parts to be lubricated, and each of them moves in a pump barrel C containing an orifice through which the oil is sucked from the tank by the piston; also, each is furnished with a jacket which, when the piston descends, prevents all back flow of oil to tank. As the useful effect begins at the instant when this jacket covers the orifice, it can be understood how the delivery of the pump can be made to vary by screwing the rod T more or less into fork F. The forced oil is conveyed by the pipe b to the point to be lubricated. H is a retaining valve which prevents the pipe being emptied.

The Henry Hamelle multiple lubricator (Fig. 559) has its mechanism in a rectangular case, which at the lower part contains the oil delivery pipes, each of which is connected with a pump N, K, whose barrel N has a stamped leather at the top and a force valve P at the lower part. Piston K has a cross-head driven by a spring which regulates its upward stroke. The oil enters the pump through the wire gauze strainer surrounding the piston K. The latter is driven downwards to force the oil by lever H, worked by crank E mounted on shaft D; the shaft is itself governed by the motor by aid of toothed wheel C, the endless screw B, and pulley A; in the groove of the pulley is placed an endless cord. The delivery of each pump is regulated by the screw which passes through lever H; when screwed down as tightly as possible there is a maximum delivery. The position of this screw can, by aid of an ingenious device, be regulated to one-sixth of a turn.

In the Rochester Pony lubricator (Fig. 560), for use especially with steam motors, a plunger pump draws oil from the metal reservoir



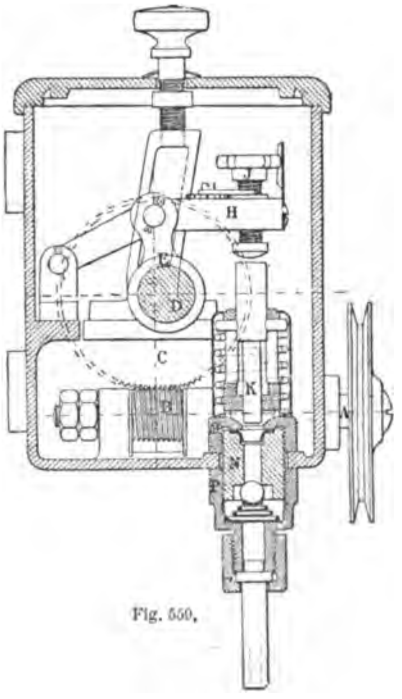


Fig. 558.—Bourdon Multiple Lubricator.
Fig. 559.—Hamelle Multiple Lubricator.

A, provided with a strainer and a hinged lid, B, and forces it out of pipe C, which leads to the steam chest of the motor. A projecting piece, D, engages in a slot in the pump plunger E, and the point of an adjusting screw, F, in the end of the plunger, comes into contact with D; thus the amount of play between plunger E and piece D is variable. The pump is operated by a rod fixed at one end to lever G, and at the other to the crosshead or other reciprocating part; holes in lever G provide for adjustment. As the lever is rocked to and fro, the ratchet wheel H and reciprocating mechanism act upon the projection D, and give a gradual backward and forward movement to the plunger E in the pump cylinder. This apparatus has the advantages of simplicity and quiet working, and the oil feed positively forced into the steam chest depends upon the speed of the motor.

The Albany sight-feed lubricator for steam motor pistons is illustrated by Fig. 561, in which A is a hand wheel permitting some of the steam passing from the boiler to enter pipe A^1 and flow out at pipe A^2, the steam on its way taking up oil fed from reservoir D. The steam supply pipe is a branch forming its own circuit with the main steam pipe. A second steam pipe from the boiler is attached at B^1, and the hand wheel B regulates the flow of steam through this connection into the reservoir D. A pipe leads down into the bottom of the reservoir D, and the steam entering at B^1 tends to force the oil up this pipe. But for this second steam supply the oil would be retarded by the steam entering at A^1. Hand wheel C controls the quantity of oil fed to the cylinders. Some steam necessarily condenses in the apparatus, and finds its way into the reservoir; consequently after a time the lubricating oil is displaced by distilled

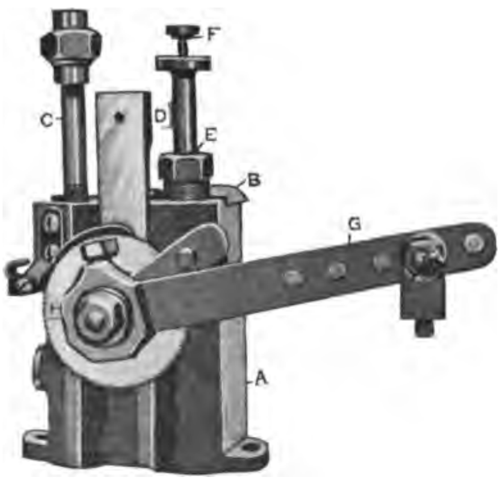


Fig. 560.—Rochester Pony Lubricator.

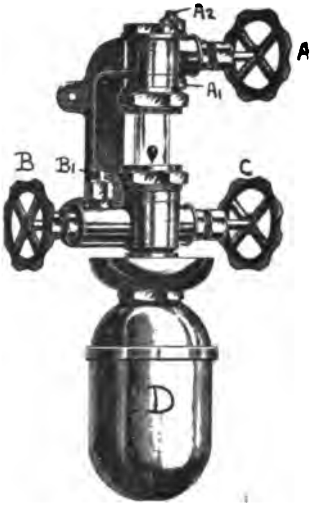


Fig. 561.—Albany Lubricator.

water. The adjustment is such that anything from twelve drops a minute to one drop in twelve minutes can be arranged for.

Dubrulle's multiple-supply lubricator, so extensively used on petrol cars, both French and British, is automatically stopped and started and maintained in working condition by the action of the exhaust gas. It is a simple appliance which may be placed in any position on the car. It will eject oil against a pressure equal to that in the motor suction pipe. The apparatus consists of a container on which is mounted a range of sight-feeds, each having a separate adjustment by means of a needle valve. These sight-feeds communicate with the fittings placed below the container by tubes passing through this but not communicating with it. The central metallic tube projecting vertically from the container connects the two sight-feeds together and supplies them with oil; another tube connects the container with the motor exhaust pipe. The pressure necessary to work the apparatus is slight, being only about 20 g. per cm.^{2} (·28 lb. per sq. in.). The motor having started, the slight pressure necessary is produced on the surface of the oil in the container, and forces oil up the central metallic tube to the range, the oil flows though the sight-feeds (the drops being in full view of the driver), and the lubrication of the parts follows. On stopping the motor, the pressure, of course, ceases, and the oil contained in the sight-feed range falls back into the contained and the lubricator ceases to act. The working of the lubricator is absolutely controlled by that of the motor, and it starts and stops without manipulation of any kind. Fig. 562 shows an apparatus with two sight-feeds, and with two auxiliary pumps, one for oil and the other for petrol spirit. This is fitted by W. H. Dorey of Paris.

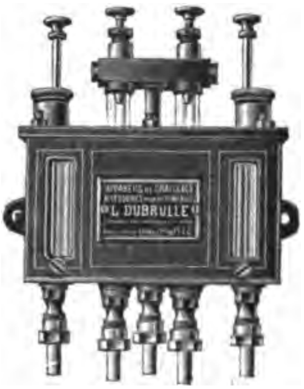


Fig. 562.—Dubrulle Multiple-supply Lubricator.

CHAPTER XVII.

STEAM AUTOMOBILE CARRIAGES.

THE plan or general arrangement of a heavy steam car should be understood easily after reading the previous chapters. The boiler and steam motor usually are placed close together in front of the vehicle under the eye of the attendant; when they are separated, the boiler is in the rear with or without an attendant. The coke bunker is within the reach of the attendant, and the water tank is hidden under the passengers' seats or under the frame of the car, an air condenser generally being on the roof. There is a toothed transmission gear with at least two changes of speed and a differential to assure independence of the driving wheels in turning corners. Endless chains or a live axle transmit motion to the wheels; there is no reversing gear, retrograde motion being obtained by reversing the motor. A brake acting directly on the wheels suffices, because the reversal of the motor is reckoned as one of the brakes; there is no special device to prevent running backwards. Two axles, one with two pivots or a pin, assure steering, there is a main frame and a body, transmission and lubricating apparatus. And now lurries and other heavy vehicles will be treated in detail.

Eight of the principal systems of heavy steam vehicles may be compared one with another as regards general arrangement by means of the diagrams, Figs. 563 to 568, which are from the *Automotor Journal.* Until just recently, steam cars on the English market were mostly of the heavy goods-delivery and haulage type, and it is interesting to note how eight of the most important builders have distributed the boiler, motor, gearing, tanks, condensers, etc. In all the systems illustrated, A denotes air fan; B, boiler; C, condenser; D, differential gear; E, engine; G, gearing; H, hot-water tank; O, oil tank; S, steering wheel; W, water tank; and X, auxiliary engine. In all but one case the boiler is in front and above; the exception is the Musker vehicle (Fig. 563), which has a horizontal boiler and a special fan or draught for the burner, placed transversely under the middle

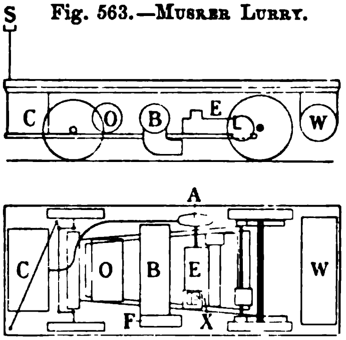


Fig. 563.—Musker Lurry.

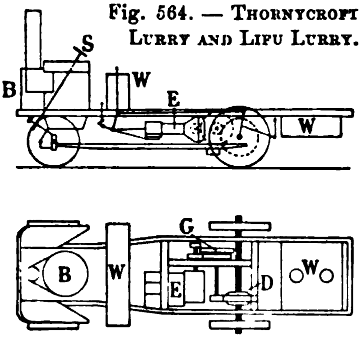


Fig. 564. — Thornycroft Lurry and Lifu Lurry.

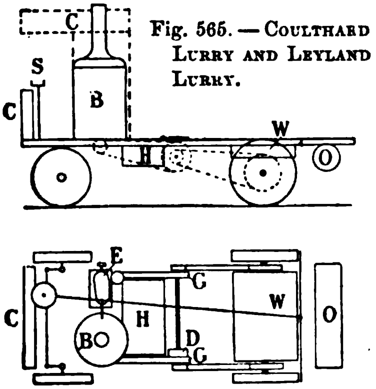


Fig. 565. — Coulthard Lurry and Leyland Lurry.

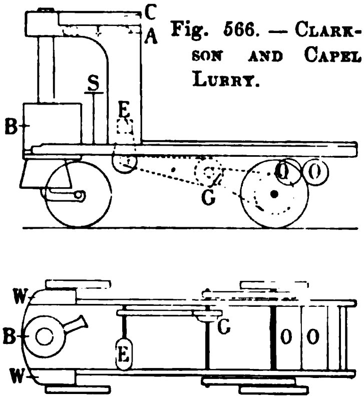


Fig. 566. — Clarkson and Capel Lurry.

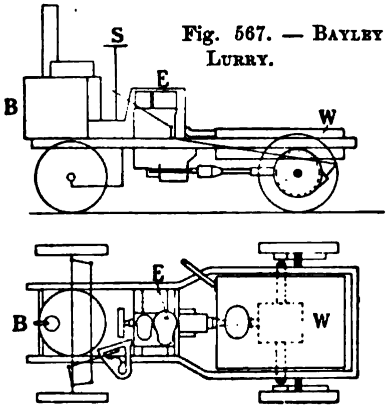


Fig. 567. — Bayley Lurry.

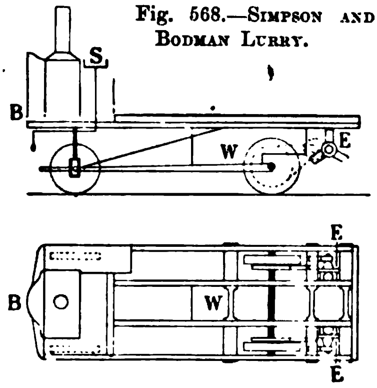


Fig. 568.—Simpson and Bodman Lurry.

of the car; a funnel is not necessary. It is important to have the boiler and motor as near as possible to the main driving wheels, in every case the rear wheels, because though when loaded the weight is largely distributed over the driving wheels, yet when running light there may not be sufficient weight upon the driving wheels to produce tractive effort if the boiler and part of the motor are carried upon the steering wheels. The positions of the motors also form a point of difference. In the Thornycroft and Lifu systems (Fig. 564) and in the Musker systems (Fig. 563) the horizontal motor is in the middle and the main driving wheel is driven by means of toothed gearing. The Coulthard, Leyland (both of these are shown by Fig. 565), and Clarkson and Capel systems (Fig. 566) have vertical motors whose motion is transmitted to the main driving wheel by chain gearing operating through a counter-shaft. The Bayley lurry (Fig. 567) has a vertical motor, and its motion is transmitted by a horizontal longitudinal shaft, which drives a counter-shaft by means of bevelled gearing, the counter-shaft driving the main driving wheel by a pinion and spur wheel. The Simpson and Bodman system (Fig. 568) has its pair of motors in a convenient and accessible position, and their weight, together with that of the gearing, tends to increase the tractive effort of the main driving wheels when running light. A further important point of difference is that the Musker, Leyland, Coulthard, and Clarkson and Capel vehicles have condensers, whereas in the Thornycroft, Lifu, Simpson and Bodman, and Bayley vehicles the superheated steam is relied on as being too hot to be visible when emitted.

The Musker steam lurry shown in side elevation by Fig. 569, and in plan by Fig. 570, is constructed on a novel system, the object being to obtain automatic control of the mechanism. Its chief features are the manner of suspension of the propelling mechanism, the boiler, and an ingenious use of by-passes; the driver's duties consist solely of regulating the steam supply to the motors and of steering the vehicle. The whole of the machinery is carried on a separate underframe, which is suspended independently by springs from, and between, the front and rear axles. The Musker flash boiler (*see* p. 68) is heated by an oil burner (*see* p. 68), and the supply of petroleum, air and water is in fixed proportions, the feeds being regulated automatically by a mechanical stoker which takes the form primarily of a constantly running auxiliary engine, and secondarily of automatically working valves. Figs. 569 and 570 show an experimental waggon, it having been converted from a horse-drawn waggon used in the Liverpool docks for loads of between 6 and 7 tons. The wooden platform A measures 5·18 m. by 1·98 m. (17 ft. by 6 ft. 6 in.), and on it is the driver's seat B; the platform is carried upon the front and rear axles C by four strong

Figs. 569 and 570.—Elevation and Plan of Musker Steam Lurry.

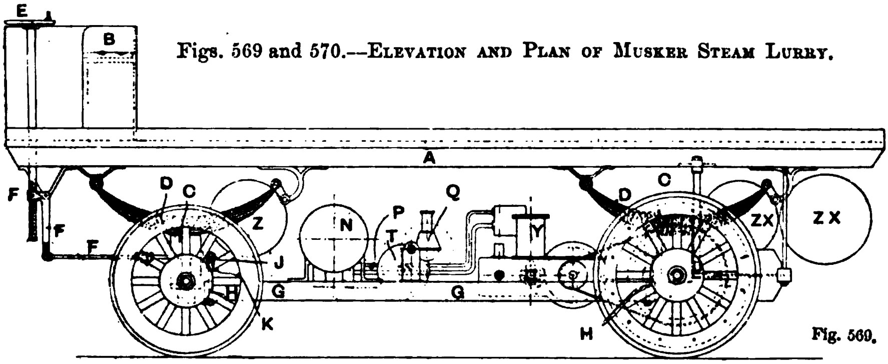


Fig. 569.

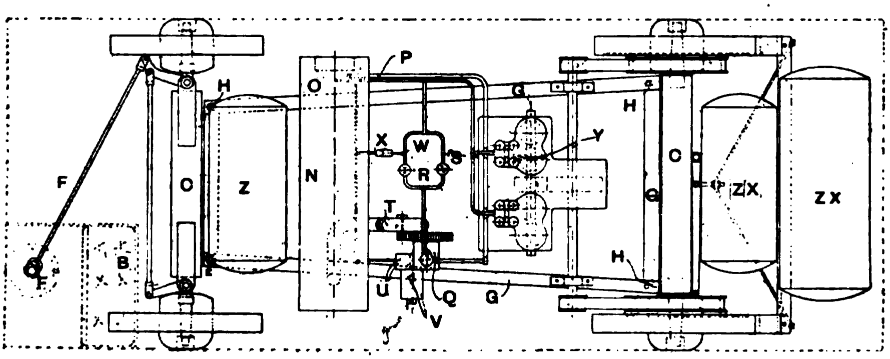
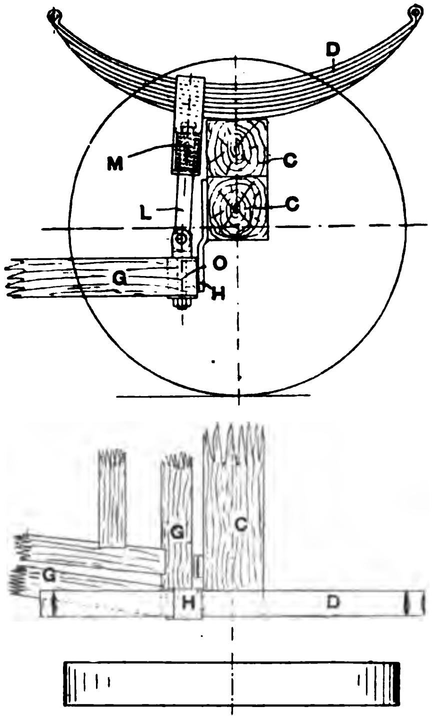


Fig. 570.

springs D. The front wheels, 91·4 cm. (3 ft.) in diameter, and fitted for steering on the Ackermann system (*see* Fig. 442, p. 436), are connected to the steering wheel E through the rods and screw F. The rear wheels, 99 cm. (3 ft. 3 in.) in diameter, are fitted with 6·34 mm. (¼ in.) steel plates bolted to and recessed into the inside of the felloes. Driving chain wheels are bolted to these plates, so that the driving power is applied direct to the rims of the wheels. Flanges bolted to the naves prevent their bushes from working loose. All the wheels have tyres 12·7 cm. (5 in.) wide. All the machinery is fixed on an oak underframe G strengthened with thin iron plates and supported from the axles C by four bolts H provided with spiral springs J of a strength to suit the load. Fig. 569 shows the attachment of the platform to the front axle, the angle plates K being secured to the axle. The attachment to the rear axle is shown in detail by Figs. 571 and 572; the suspension bolts H are connected by a joint with the rods L, and the springs M are enclosed. The other letter references in these figures are the same as in Figs. 569 and 570, in which figures the boiler N is shown fixed across the underframe; it has three tubular concentric coils, a liquid fuel burner being fixed to and forming a continuation of the boiler. The burner lies to the left-hand side of the underframe, and the feed-water (O) and steam (P) connections to the right-hand side. The mechanical stoker is indicated in Figs. 569 and 570; its parts are: a small auxiliary motor, Q, supplied with steam from the boiler through pressure-reducing valves R and S; a centrifugal fan, T, driven by toothed gearing at a high rate of speed and delivering air to the burner; oscillating, valveless pumps U and V driven by a half-speed shaft and supplying water and oil respectively to the boiler, the pump ports being opened and closed by the movement given them by the auxiliary motor; and an automatic throttle valve W, and a pressure device X. Valves R and S are set to give pressures respectively of 7 kg. and 3·5 kg. per cm.^{2} (100 lb. and 50 lb. per sq. in.). The action of the parts forming the mechanical stoker is as follows:—When the motor Q is supplied with steam at



Figs. 571 and 572.—Attachment of Platform to Rear Axle of Musker Lurry.

3·5 kg. per cm.^{2} (50 lb. per sq. in.) through the valve S only, it is barely possible to supply sufficient air, oil, and water to the boiler to maintain the necessary amount and pressure of steam required to make up for condensation, waste, and for its own consumption. As soon, however, as the boiler pressure begins to decrease, the pressure in the feed-water pipe and consequently in the pressure device X also decreases, and the throttle valve W then opens. In this way steam at a pressure of 7 kg. per cm.^{2} (100 lb. per sq. in.) passes from the valve R to the auxiliary motor, and it then runs at a higher speed and delivers more fuel and water to the generator. Thus, under working conditions, the automatic valve W continually is regulating the speed of the auxiliary motor and thus keeping the boiler pressure constant, in spite of variations of load. Two constant, adjustable by-passes in the delivery pipes from the oil and water feed pumps allow a certain quantity of the feed to return to the respective supply tanks; also there is an automatically controlled by-pass in the steam-pipe supplying the auxiliary motor. The main motor Y has four cylinders, and makes 500 revolutions per minute, at which speed the waggon travels at 8 km. (5 miles) per hour. The normal working steam pressure is 17·6 kg. per cm.^{2} (250 lb. per sq. in.), and the steam is superheated to 315·5° C. (600° F.). The oil tank Z in front of the boiler holds one day's supply, 113·5 l. (25 gal.), and the water tanks Z X, holding 650 l. (144 gal.), more than half a day's supply, are fixed at the back. Lack of space prevents a fuller description here of what is a very interesting and important attempt at steam car construction on new lines; but it may be said that since the above experimental car was made the same makers have introduced their commercial type, little differing from the one here described. One type of Musker waggon uses coke fuel, and in this the automatic devices are retained partly, but an auxiliary motor is not used.

The Thornycroft Steam Waggon Company, of Chiswick, had a tractor intended to haul a 5-ton dray. Two spiral gear wheels on the driving shaft could each gear with the differential wheel, thus giving ratios of reduction of 12 to 9 to 1. Renolds chains transmitted power from the differential shaft to the toothed wheels of the rear driving wheels. The steam brake exerted a pressure of 2,280 kg. (5,016 lb.) on the driving wheel naves, and screw brakes operated shoes on the tyres of the same wheels. Steel exclusively was employed for building this tractor, excepting the motor attendant's cab, which was made of oak. The hauled dray, the platform of which was steel or wood (steel is preferable because it gives a lighter floor, without being too noisy during motion), had only two wheels. Its fore part rested on the rear of the tractor on a hinged steering ring, allowing vibrations in two vertical planes. The wheels of this dray had a screw brake. Its platform is 10 m.^{2} (107·6 sq. ft.); the weight of the tractor and dray empty was 3·91 tons, and with water and fuel it was 4·32 tons. The loaded dray was hauled at a speed of 8 km. (4·97 miles) per hour on the level, and express speed was possible only when the dray was empty. The same company entered at the Liverpool trials of 1898 a steam lurry of 2·5 tons useful load, with an available surface of 5·5 m.^{2} (59·2 sq. ft.), and weighing slightly more than 2·8 tons empty.

The Thornycroft Steam Waggon Company's 7-ton lurry has a frame built of channel steel, and a platform built of oak and steel. The frame (*see* Figs. 573 and 574) is supported upon the rear axle by semi-elliptic springs, and is carried above the front axle by a single transverse spring. A special arrangement of horn plates ensures flexibility and a three point suspension, coupled with strength and rigidity in the necessary planes. The boiler (p. 53) is fixed to the framework just behind the front axle, and between it and the front of the waggon a centrally arranged funnel K and a combined feed heater and exhaust silencer J are placed. The boiler cover M, and an adjustable door R in the ash pan serve for regulating the draught, the latter being controlled by a sliding rod in the floor on the left-hand side of the driver. A spark arrester is fixed in the funnel. To the right of the driver's seat N is a reversing gear handle S mounted with the usual quadrant, and this has two forward notches corresponding with cut-offs of $\frac{5}{8}$ and $\frac{7}{8}$, besides the intermediate and the reversed positions. There is a handle for regulating a by-pass on the delivery pipe from the force-pump through the feed heater to the boiler. The coke bunkers on each side of the boiler hold sufficient for an 80 km. (50-mile) run. Four cocks to which steam can be admitted from a single cock near the throttle valve on the boiler are fixed to the bunker on the right-hand side, and they distribute steam to either of the four following parts:—A water filter, for filling the tanks, steam blast for accelerating the raising of steam, a by-pass for admitting live steam to the low pressure cylinder, and a steam jet for cleaning the boiler tubes. The larger of the two water tanks is placed beneath the frame at the back of the vehicle, and the second one is on a higher level and gives a head of water both to the pump and to the injector. The two-cylinder compound motor A (p. 99) is fixed horizontally beneath the framework, and is completely cased. The exhaust steam, after passing through the feed-heater, is taken into the smoke box and discharged

Figs. 573 and 574.—Elevation and Plan of Thornycroft Steam Lurry.

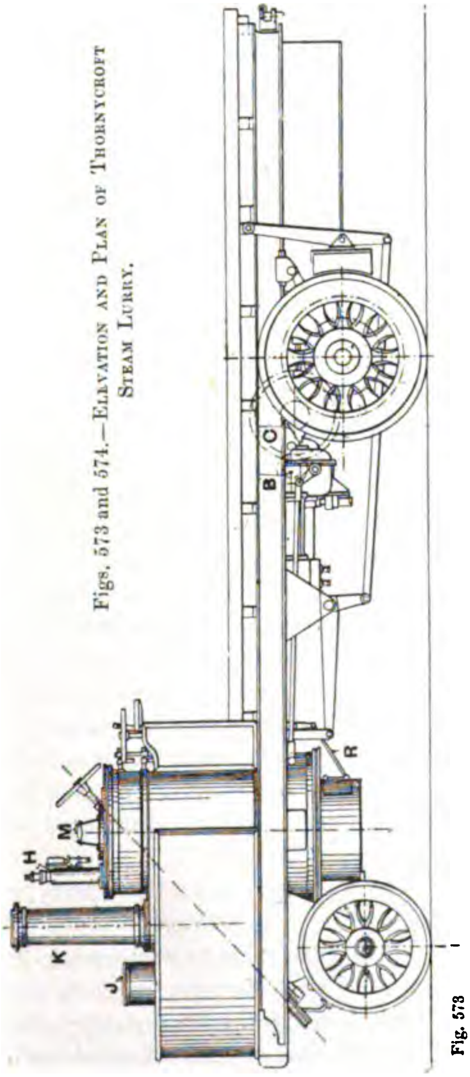


Fig. 573

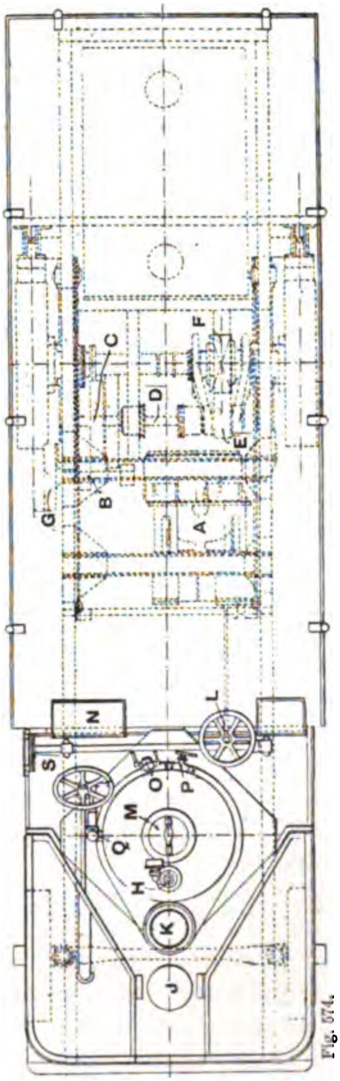


Fig. 574.

invisibly from the funnel. The transmission gear consists of two machine-cut pinions riding upon a square part of the motor shaft, and either of them may be made to engage with corresponding spur wheels C on the countershaft. The countershaft is divided into three pieces, C, D, and E, with special universal joints between them; and the portion carrying the spur wheels follows the motions of the motor and frame. The intermediate part serves as a flexible coupling between the first part and a third part, and allows of the remainder of the transmission gear following the movements of the rear axle. Power is transmitted from the countershaft to the differential gear F on the axle by a pair of double helical cast-steel pinions. The portion E of the countershaft is carried in a pair of brackets mounted about the rear axle and stayed by a link hinged to the underframe. This device is known as the Thornycroft patent bell crank drive. The rear wheels are driven from the differential gear through flexible drives, leaf springs being replaced by an arm carrying four helical springs in compression. The central member of the rear axle is carried through from end to end; on the left-hand side of the lurry, where it passes through the sleeve, driving the road wheel, it carries a kind of band brake, which normally rides freely about a drum, forming part of the rear wheel. This brake can be caused to grip the drum and in this way lock the differential gear. Steering is on the Ackermann system, the inclined shaft and hand-wheel being illustrated. A second hand wheel L on a vertical shaft is connected through a screw and strong connecting rods to a pair of block brakes acting on the rear wheel tyres. Letter references in Figs. 573 and 574 not yet explained are B, crank-shaft; G, outside fly-wheel; H, pressure gauge; O, water gauge; P, injector; and Q, throttle valve.

The Liquid Fuel Engineering Company (Lifu) had a lurry carrying 2 tons. The boiler (p. 54) and 25 h.p. motor (p. 97) are in front. A first longitudinal shaft, inclined and telescopic so as to compensate for the displacements due to suspension of the machine, receives and transmits motion by bevel gear. A second transversal shaft carries toothed pinions which gear interiorly with the wheels. A single ratio of reduction is 8 to 1. Two sand boxes facilitate starting on a slippery pavement. A pedal brake acts on the rear wheels. The underframe, made of soft steel with wooden wheels and bronze naves, carries two petroleum tanks each of 90 l. (19·8 gal.) capacity, and two water

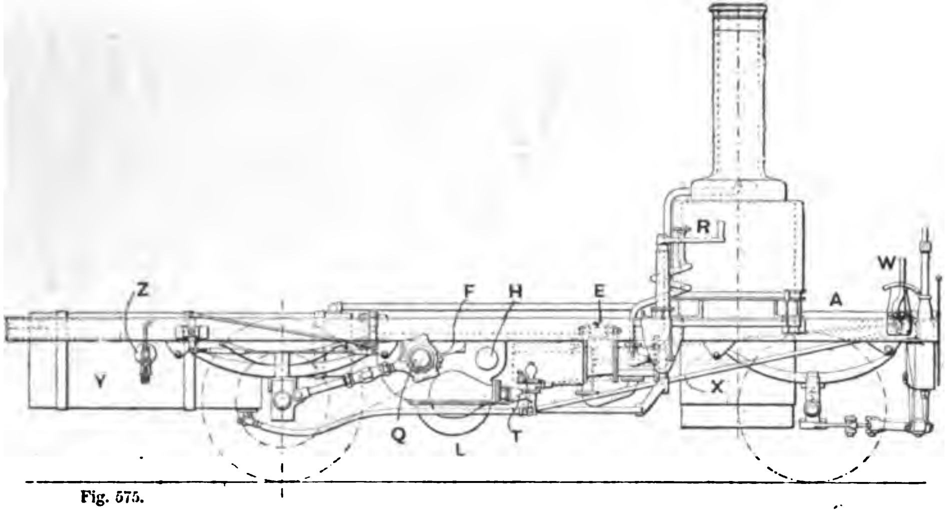


Fig. 575.

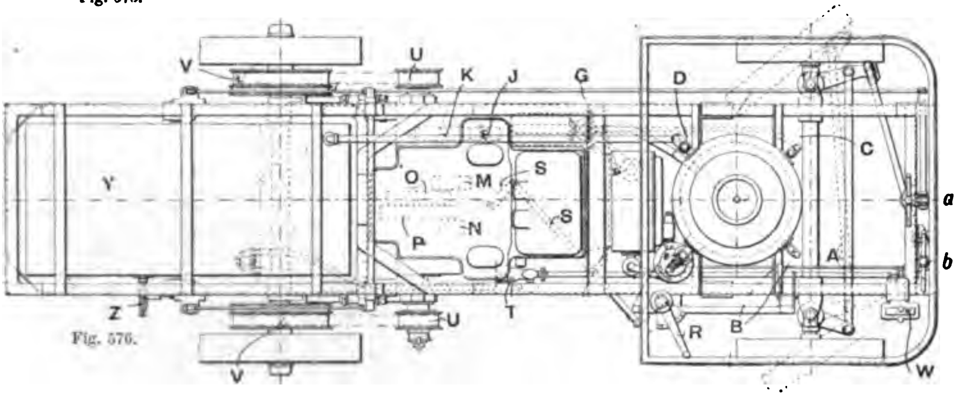


Fig. 576.

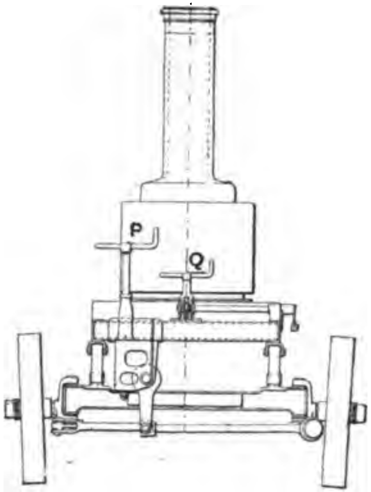


Fig. 577.

Figs. 575 to 577.—Elevations and Plan of Coulthard Steam Lurry.

tanks holding 270 l and 340 l. (59·4 gal. and 74·8 gal.). Empty, the vehicle weighs 2,425 kg. (47 cwt. 71 lb.). With 600 revolutions per minute the motor gives a speed of 13 km. (8 miles) per hour on a level, and 6 km. (3·7 miles) on a rising gradient of 1 in 10. This lurry took part in the Liverpool trials of 1898.

The Coulthard steam lurry is shown in elevation by Fig. 575, in plan by Fig. 576, and in front elevation by Fig. 577. The frame is of channel steel and is supported on semi-elliptical springs fixed at their centres to the front and rear girder axles of cast steel. The vertical fire tube boiler is bolted by bearer bars to the main frame centrally behind the front axle. The foot-plate is below the level of the framework, and the boiler is fired from beneath. The driver's seat A is in front of and to the right-hand side of the boiler. (For particulars of the Coulthard boiler, *see* p. 40.) The water gauge B and steam gauge are in front of the boiler, and the steering wheel, on its vertical pillar, is immediately in front of the driver. To his right hand are two small levers working in quadrants, one regulating the reversing gear, and the other being connected to the throttle valve. On the feed pipes from an automatic force pump driven by the second motion shaft and of a steam pump fixed behind the driver, are safety pattern check valves C and D. A large throttle valve is fixed upon the boiler directly behind the driver, and the steam jet also passes from the same place. The throttle valve regulates the flow of steam through a spiral and flexible steam pipe which communicates with a special distribution valve fixed to the motor casing. The motor, second motion shaft, and differential gear shaft, are all enclosed in an oil-tight casing, and are supported at three points, the one immediately over the back of the cylinders being a pivot, as shown at E, and the others being spherically mounted bearings F on the compensating gear shaft. The motor is illustrated by Figs. 76 and 77, p. 100. The steam regulator is a balanced valve, attached to the high pressure cylinder steam chest, and so arranged that the steam supply can be regulated quickly by the handle on the driver's right hand. A combined feed water heater and exhaust silencer G is attached to the outer side of the low pressure cylinder. The crank shaft H is carried in two long bearings, together with the eccentrics, is made in one piece, and carries on its left-hand end a pinion J, which gears with a corresponding wheel K on a second motion shaft L; a pair of unequal sized pinions

M and N slide on a square on this shaft, and either of these may be caused to engage with corresponding wheels O and P upon the crown of the differential gear upon the shaft Q. The pinions M and N are operated by handle R behind the free position through the connecting links S. The feed pump T is so constructed that the stuffing box and valve boxes are easily accessible, but that the ram is not exposed to dust. The differential gear shaft Q alone projects through the casing; the compensating gear shaft and transmission gear are described on p. 281. The power is transmitted by Renolds silent chains from the chain wheels U to large wheels V fixed to the felloes of the rear road wheels. (The new Coulthard transmission is described on page 366.) Distance rods, which take the driving thrust, are pivoted to the back axle and to the compensating gear brackets. The large chain wheels are fitted with the Coulthard triangular drive, which is a device whereby the power is applied direct to the felloes instead of to the spokes. The reversing lever W is connected to the link motion gear by the rods X, and is provided with slots affording three different positions of cut-off in a forward direction and one intermediate position, as well as a reverse position. The water tank Y is beneath the frame at the back of the waggon, and is fitted with a water lifter Z. Two powerful double-acting band brakes, consisting of steel cables lined with hard wood blocks, are coiled round the brake drums on the back wheels, and are so arranged that both of the ends of the cable are tightened or released simultaneously by the action of the brake handle *a* on the left-hand side of the driver. The connection between the handle and the brakes is made by means of the usual worm and worm wheel, and by a simple system of levers. The platform can be slid backwards on rollers, and is hinged at the back end in order to enable the motor and other parts to be examined. The artillery pattern wheels are fitted with cast steel hubs having bronze bushes, oak spokes, and English ash felloes. The steering gear is a modification of the Ackermann system, and is operated from the horizontal steering handle *b* in the ordinary manner.

The Lancashire Steam Motor Company's lurry (the Leyland) is shown by Figs. 578 and 579; it carries 4 tons useful load, has a compound stamp motor, its cylinders have bores of 75 mm. and 125 mm. (2·95 in. and 4·92 in.) respectively, and the common piston stroke is 150 mm. (5·9 in.). At 500 revolutions per minute it gives 14 h.p. It is not reversible, and forward and backward motion of the vehicle are obtained by aid of a coupling gear. On some lurries there are two transmissions instead of one, the first by toothed gear and the second by a chain, one of them being employed for forward motion and one for backward motion. It is not clear why a reversible motor is not employed. Renolds chains unite the first intermediary shaft with the differential shaft and the latter to the rear driving wheels. The ratios of reduction between the motor shaft and the axle are 8 : 13½ and 28 : 1. Two powerful brakes can stop the car in half its length, each of them being able to hold back the dray on a falling gradient of 145 in 1,000. The underframe is steel and the wheels are wood. The floor gives an available surface of 7·25 m.^{2} (78 sq. ft.); the weight empty is 2·91 tons. This lurry took part in the Liverpool 1898 trials.

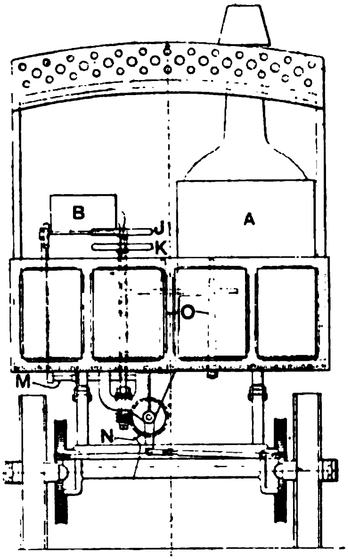


Fig. 578.—Front Elevation of Leyland Steam Lurry.

One type of omnibus built by the same company carries six passengers inside and 500 kg. (1,100 lb.) of luggage on the roof, and is driven by a 6 h.p. motor. The consumption of petroleum for 65 km. (40·4 miles) is 31·801 l. (7 gal.)

Referring to the Leyland 4-ton lurry, shown in front and side elevation respectively by Figs. 578 and 579, its frame is built of channel steel, upon which is a platform having an available cargo area of 6·59 m.^{2} (71 sq. ft.). The framing is connected, through double plate springs, to the axletrees, which are of heavy section wood, and have at their ends iron shoes to which are attached the axles proper. The wheels are of wood and all the same size, 99 cm. (3 ft. 3 in.) in diameter, and the rear wheels have 12·7 cm. (5 in.) tyres, and sprockets for the driving chains are bolted to them. The fore wheels are pivoted in iron jaws, and steering is effected by worm wheel and connecting rods. Of the two brakes, one is a hanging brake acting on the rear wheels and worked by a worm and wheel arrangement from the starting platform, and the other is a band brake working on the transmission gearing. The vertical fire tube boiler (*see* p. 39) is placed on the fore platform to the left, and common petroleum is burnt under it, the oil vapour supply being controlled by the Spurrier automatic valve. The petroleum tank is carried under the platform at the rear end and holds 90 l. (20 gal.), whilst the 227 l. (50 gal.) water tank is situated midway under the framing. The 14 brake-horse-power, two-stage compound motor runs at 400 revolutions per minute, and is fitted with a Pickering governor. In the roof of the cab, enclosing motor and boiler, is an air condenser consisting of indented brass pipes. As regards transmission, the motion of the main shaft is transmitted to an intermediate shaft by chain gearing and thence to the rear wheels, also by chains. The three speeds are 9·6 km., 5·6 km., 3·2 km. (6 miles, 3·5 miles, and 2 miles) an hour respectively on ordinary good roads. The wheel base is 3·02 m. (9 ft. 11 in.), the gauge is 1·6 m. (5 ft. 3 in.), and the weight, light, is 2·85 tons. In Figs. 578 and 579, A indicates boiler; B, motor; C, water tank; and D, the feed pipe from it; E, drain tap; F, feed pump; G, oil tank; H, condensers on roof; J, hand steering wheel; K, brake wheel; L, starting and band brake lever; M, band brake shaft; N, steering gear; and O, clutch levers.

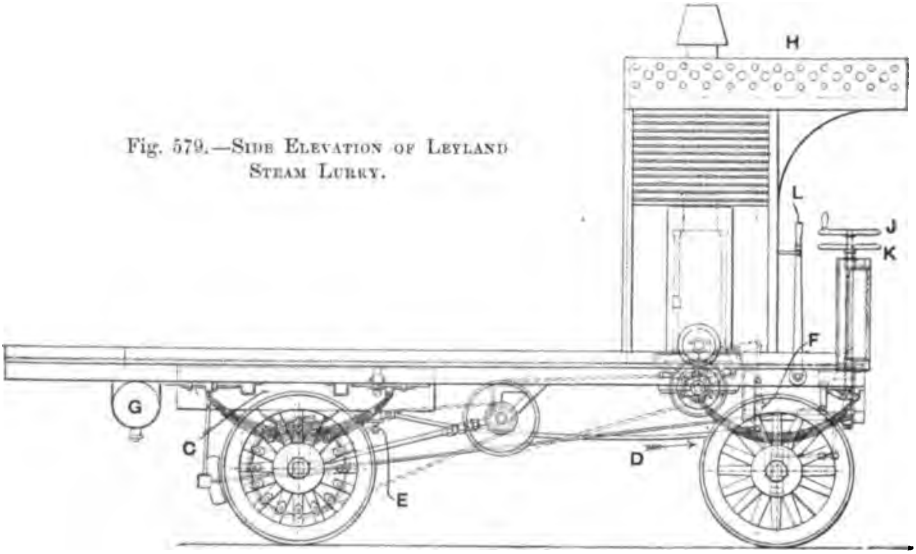


Fig. 579.—Side Elevation of Leyland Steam Lurry.

In a more recent type of Leyland lurry, the feed-water pump is driven off the countershaft; it has double valves, and its delivery to the boiler is controlled from the driver's seat by returning some of the water through a by-pass to the main tank. Special side band brakes are fitted; a number of wood blocks strung on a flexible wire cable act as the bands and ride between the flanges of the drums. Renolds roller chains are employed. By employing cast steel largely in the construction, it has been possible to make some of the gear wheels in one piece, with their hollow shafts, and others are secured by flanged couplings, thus dispensing with keys and similar devices. The rear axle is of Mannesman steel tubing, whilst the motor shaft is a solid forging complete with eccentric blocks, counterweights, and flanges for connecting the gear wheels. A distinct type of Leyland 7-ton lurry is gear-driven, side chains not being used.

The Clarkson and Capel 3-ton steam lurry is shown in elevation by Fig. 580 and in plan by Fig. 581. The steel framing supports a platform having an area of 6·1 m.^{2} (66 sq. ft.), framing and platform being carried on plate springs attached to steel axletrees. The military type wheels have metal hubs, the wheel base being 3·02 m. (9 ft. 11 in.) and the gauge 1·6 m. (5 ft. 3 in.). This vehicle shows several departures from existing practice, the details being very ingenious. The Merryweather fire-engine type boiler A is in front, and the liquid fuel burner used is illustrated by Fig. 12, p 43. The two-stage compound vertical marine type motor B runs at a speed of 500 revolutions per minute, is placed with the boiler on the fore platform and enclosed in a cab on whose roof is an air condenser C formed of rows of thin tubing, air being forced through them by a horizontal propeller fan D driven by rope and pulley off the main shaft. Transmission is by chains from the main shaft E to an intermediate shaft F, upon which is differential gear, and thence to the rear driving wheels. The two speeds possible are 9·6 km. and 3·2 km. (6 miles and 2 miles) per hour on good roads. An emergency steam brake is fitted to each driving wheel, and comes into operation by a reverse movement of the steam regulation lever. A pedal operates a band brake G on the motor shaft. Steering is effected by the usual worm and screw, the hand-wheel H being on a vertical spindle. The water tanks J, one each side of the boiler, hold 230 l. (50 gal.), and the oil fuel tanks K are hung underneath the rear part of the vehicle and hold 120 l. (27 gal.). When light, the lurry weighs nearly 3 tons.

The Bayley steam lurry, shown in side elevation by Fig. 582, in plan by Fig. 583, in front elevation by Fig. 584, and in rear elevation by Fig. 585, is the subject of some claims for remarkable

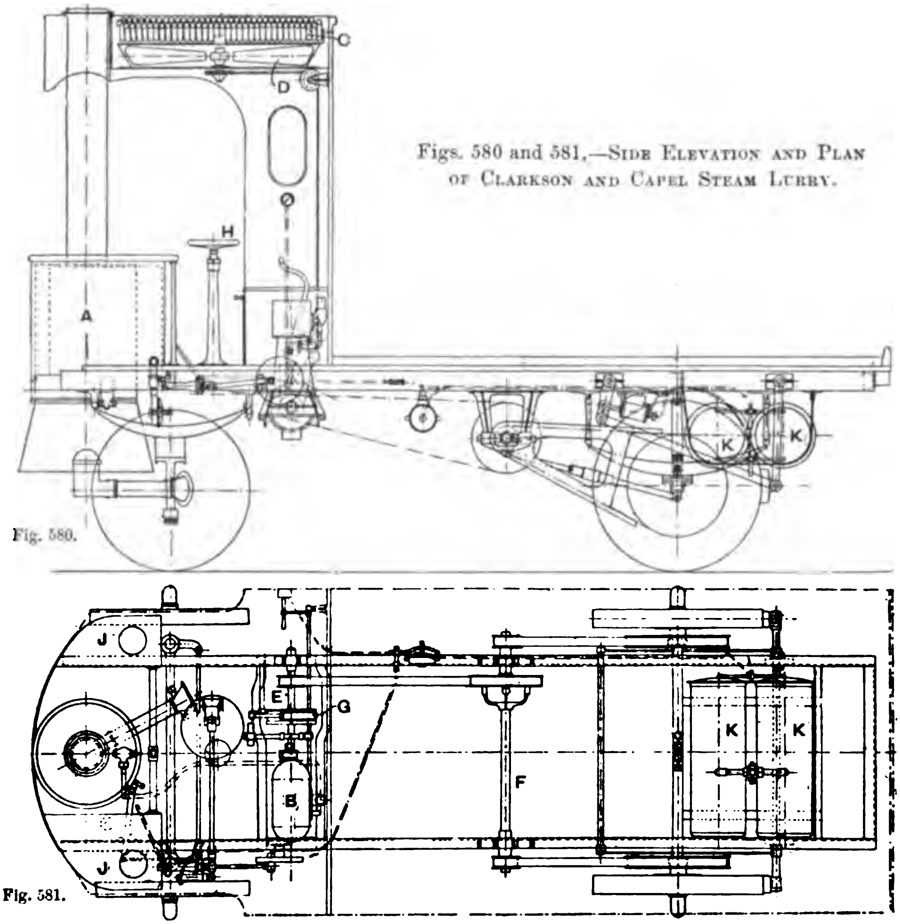
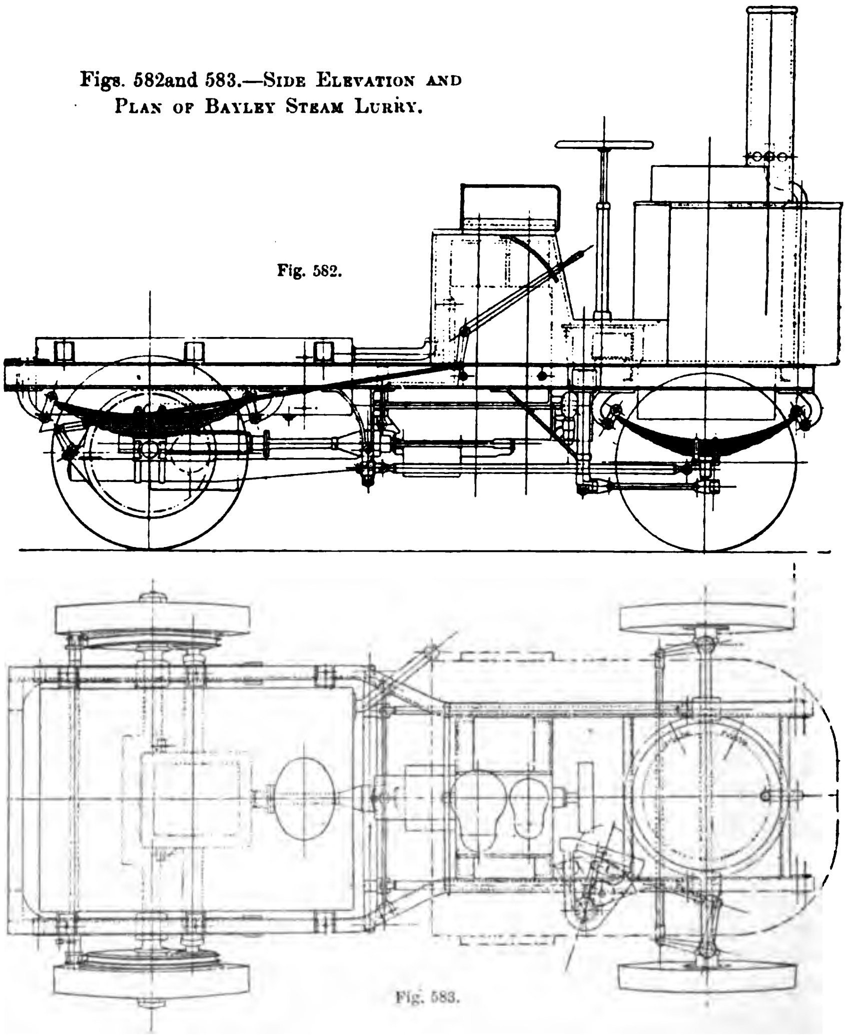


Fig. 580.

Fig. 581.

Figs. 580 and 581.—SIDE ELEVATION AND PLAN OF CLARKSON AND CAPEL STEAM LURRY.

efficiency. It is built of channelled steel, and the platform has a cargo area of 6 m.^{2} (65 sq. ft.) and can carry from 3·5 tons to 4·5 tons. Ordinary waggon springs with link suspension carry the framing, and the fore axletree is curved to permit of access to the boiler ashpit, its ends terminating in sockets, in which are the pivots attached to the axles of the fore wheels. The rear axletree is a massive iron forging of square section about 10·16 cm. by 10·16 cm. (4 in. by 4 in.) in the middle, and bent in a horizontal plane to allow room for the casing containing the differential and bevel transmission gear. The military type driving wheels are 88·9 cm. (2 ft. 11 in.) in diameter, and have dished tyres 12·7 cm. (5 in.) wide; the wheel base is 2 m. 59 cm. (8 ft. 6 in.), and the gauge 1 m. 72·7 cm. (5 ft. 8 in.). Upon each rear driving wheel is bolted an internally toothed wheel, into



Figs. 582and 583.—Side Elevation and Plan of Bayley Steam Lurry.

Fig. 582.

Fig. 583.

which gear pinions at the ends of the differential shaft, and so the motion is transmitted. Band brakes act upon the external periphery of the internally toothed wheels. The compound motor is constructed under the Straker patents, is wholly enclosed, and is placed longitudinally, the main shaft lying fore and aft and driving the differential shaft by means of enclosed bevel gearing, all of which runs in oil. Suspension of motor and gearing is ingenious, and the two ratios of gearing respectively are 13·7 to 1 and 8·4 to 1. The boiler is on the fore platform and is of the de Dion-Bouton " Pot " or centrally fired type, and contains 86 l. (19 gal.) of water; the fu elis coke, and 150 kg. (3 cwt.) of it is carried. A feed pump is on the motor and an injector near the boiler, and the feed tanks are placed between and under the framing in the after part, their capacity, including that of the tank on the platform, being 372 l. (82 gal.).

Figs. 584 and 585.—Front and Back Elevations of Bayley Steam Lurry.

Fig. 584.

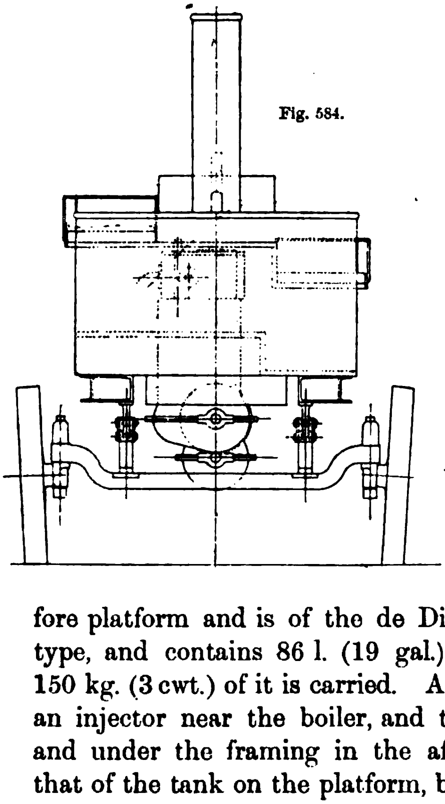
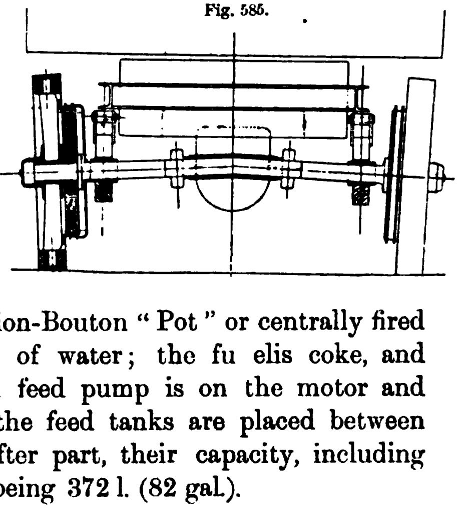


Fig. 585.



The general arrangement of the Simpson and Bodman steam lurry is shown by Figs. 586, 587, and 588; Fig. 586 being a side elevation, Fig. 587 a plan of the platform, and Fig. 588 a front elevation. Fig. 586 shows the framing to consist of four longitudinals connected by two transverse frames in the rear. This rear framing is supported by four plate springs of very deep camber, so arranged that each spring is directly under one longitudinal bearer. To these plate springs is attached the main or driving wheel axle. Each driving wheel is mounted between a pair of springs, and thus the axle is supported throughout its length. The rear axle is a weldless steel tube with the axle arms case-hardened and ground true, and it carries four spring bearings, the two outer ones being at extremities. These bearings are recessed to make dust-excluding shrouds for ball thrust collars for each adjustment to the wrought iron axle bushes, which are run up with anti-friction metal, and are of such a surface that, assuming one-third of the circumference as carrying load, they never can have more than 9 kg. per cm.² (130 lb. per sq. in.) of load on them. The method of attaching the rear or

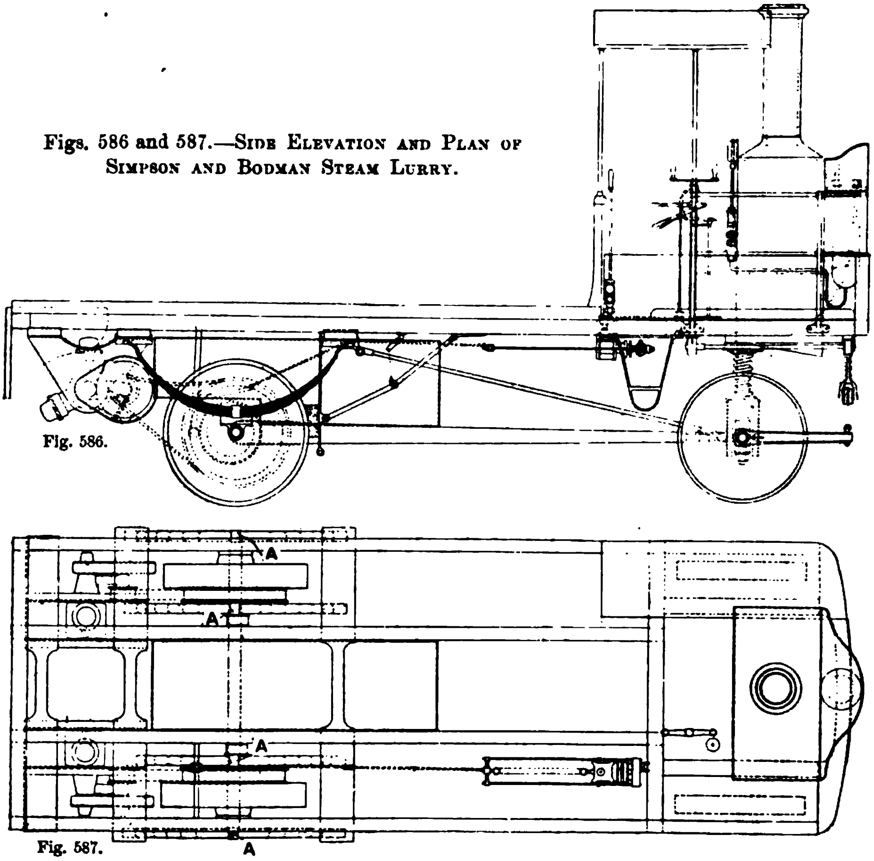

Figs. 586 and 587.—Side Elevation and Plan of Simpson and Bodman Steam Lurry.

Fig. 586.

Fig. 587.

driving wheel to the framing is clearly illustrated by Fig. 586. Lubrication is assured by filling the axle for 18 in. from each end with solidified oil and providing an oil hole in the base of the arm. The fore part of the framing is carried through spring loaded pins attached to a transverse wood framing reinforced with steel plates (*see* Fig. 588). To this transverse framing is attached the fore axle, and also, by means of a central bushing (*see* Fig. 588), the two ash perch bars (*see* Fig. 586) connecting the two axles. The perch bars are united to the rear axle by circular steel collars, which embrace discs formed on the axle, but keyed eccentrically; this is for the purpose of obtaining a rapid and fine adjustment for the chain drive. The front axle is free to oscillate vertically with respect to the main framing, a most important point; the same principle is seen in the bogies of locomotives and railroad cars. The fore axle is bifurcated at its ends, and is fitted with bell crank axles, upon which the free wheels are mounted and to which the steering rods are attached. The usual bell crank arm is carried outside the wheel to dispense with the welded crank usually employed, this weld being difficult to make and interfering with the locking of the arms; the bell crank is very long, to obtain leverage. The lurry will turn in a circle two and a half times its own length in diameter. The steering is by worm and screw, actuated by a vertical spindle placed close to the driver (*see* Fig. 586). The available platform area of the frame shown in Fig. 587 is 7·8 $m.^2$ (84·5 sq. ft.). The wheels have oak spokes, designed to work on the parallel arms. The Simpson and Bodman boiler is illustrated by Figs. 42 to 44, p. 67, and the motor by Figs. 64 and 65, pp. 88 and 89. There are two motors, one on each side, each actuating its own driving wheel, and having nothing in common save the steam and exhaust pipes. Each crank shaft carries a steel pinion gearing into a bronze spur wheel on a short shaft carried in brackets attached to the motor casing, and on these brackets are the chain

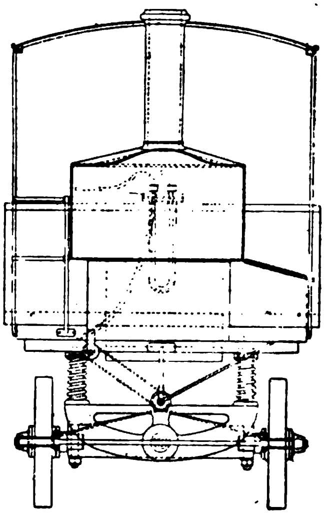


Fig. 588.—Front Elevation of Simpson and Bodman Lurry.

pinions from which motion is transmitted to the main driving wheels. There are no clutches for effecting changes of speed, but there are three sets of pinions and wheels for each vehicle, giving ratios of 10, 13, and 24, and the ends of the crank shafts and second shafts are so arranged as to allow for a very quick change of gear; the nuts that lock these gears in position on being unscrewed draw the pinions and wheels of the shaft.

Straker lurries are of 5-ton and 7-ton capacity, and in both vehicles the general arrangement of parts is similar. The 7-ton vehicle is shown by Fig. 589. The main frame of strong channel steel is stiffened with cross-members, and an additional longitudinal member passes from a cross-member just behind the cab to another just in front of the back axle. The motor is fixed horizontally between this longitudinal member and the left-side member of the frame. The cylinders lie forward, and the crank shaft projects across the frame outside the crank chamber. It here carries two pinions, either of which can alternatively be slid along the shaft into mesh with corresponding spur wheels on a countershaft. The power is transmitted from this countershaft to the live rear axle by a twin-roller Brampton chain, which, for the large vehicles is tested to 30 tons, and for the smaller lurries to 20 tons. The double-acting compound motor has a single-eccentric reversing gear, in which a square block slides in a slot in the eccentric block; the eccentrics for the two cylinders are controlled simultaneously. The motor on the large lurry is of 40 h.p. The wheel base is 3·5 m. (11 ft. 6 in.), the track of the rear wheels is 1·6 m. (5 ft. 3 in.), and that of the front wheels 1·37 m. (4 ft. 6 in.). The overall length is 6·55 m. (21 ft. 6 in.), and the water tank, carried at the rear, contains 900 l. (200 gal.). The feed-water pump is driven at a low speed through spur gearing off the left-hand end of the crank shaft. The motor is entirely enclosed, and when necessary high-pressure steam can be admitted to the low-pressure cylinder. The differential gear is locked when necessary by inserting a pin through one or the other of a series of holes arranged in the hub of the right-hand wheel. A central solid axle passing through both of the hubs is rigid with the left wheel, and with a disc outside the right wheel hub. The right-hand wheel itself is connected by a sleeve with the differential gear; the sleeve runs freely about the solid axle. The locking pin is inserted through corresponding holes in the disc on the solid shaft and in the hub of the road wheel. The suspension at the rear is by semi-elliptic side-springs, the ends of which are free to slide in guides on the frame. Two transverse inverted springs form the front suspension (see Fig. 590). They lie in front and behind the axle, and are carried at each end by swinging links from the axle itself. The central portions of the springs are fixed to the under member of a ball-bearing turntable, and the front axle is pivoted centrally by a horizontal pin, and is also capable of vertical movement between horn-plates. The vehicle is steered by a hand wheel connected through bevel and worm gearing with the turntable. The boiler fixed above the turntable is of the De Dion type; the tubes connecting the two annular spaces are of large diameter. The road wheels on the 7-ton lurry are built up of stamped steel plates with flanged rims, the spokes being formed by the two plates interlacing; in future the wheels will be made in the same way as those on the smaller

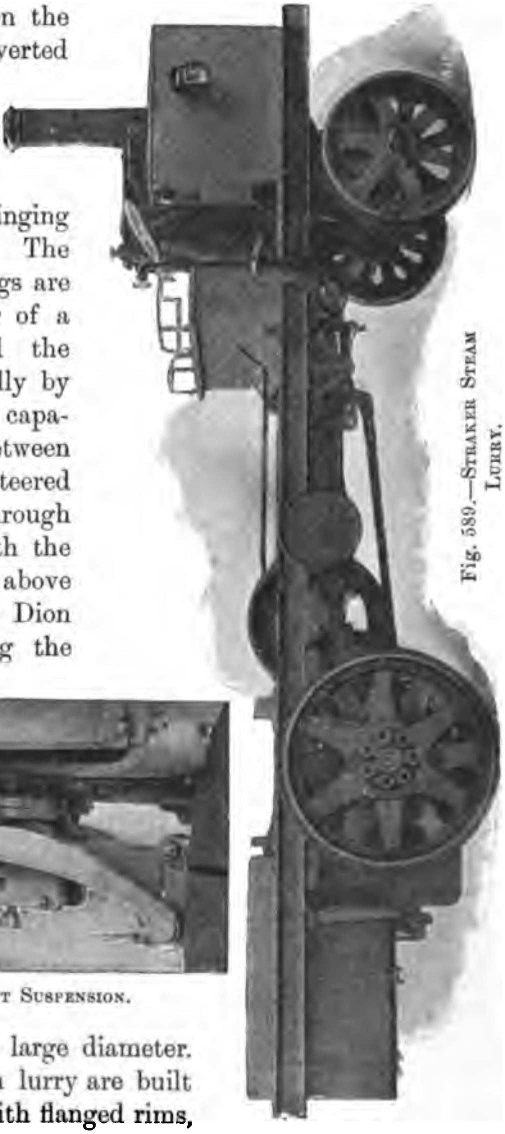


Fig. 589.—Straker Steam Lurry.

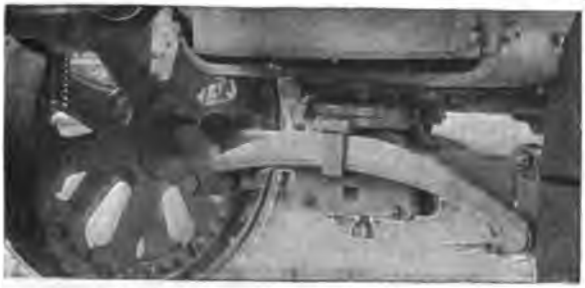


Fig. 590.—Straker Front Suspension.

lurry; that is, simpler, of a less number of pieces, stronger and more durable. The treads of the tyres are cross-grooved to ensure adhesion to the road.

The Foden steam lurry is illustrated in elevation by Fig. 591 and in plan by Fig. 592, which show it to be of novel and interesting design, somewhat resembling a small high-speed traction engine and a lurry combined. The locomotive type horizontal boiler B forms the front end of the channel steel frame A, and its fire-hose end C backs on to the driver's cab D. During the trials above referred to the boiler was fired with coal, and steam was raised in about forty-five minutes. The compound horizontal motor E is mounted traction-engine fashion on the top of the boiler, towards the fire-box end being the crank shaft F, carrying fly-wheel G; it has link reversing gear and a special device for admitting steam into the low pressure cylinder. Below the crank shaft, and gearing with it by means of one or two sets of spur wheels H J is a parallel countershaft K, power from which is transmitted to the line rear axle by two roller chains L working side by side and running on chain-wheel rings mounted on the periphery of the differential gear case O. The rear axle has external bearings free to move vertically in guides on brackets M attached to the frame A, and the load is supported by a single plate spring N at each side; in front the load is carried by a single cross spring P attached at its centre to the lower locking plate Q, and resting at each end on the front axle. Steering is accomplished by turning the axle about a central pin, the usual hand steering wheel being in the driver's cab; the manœuvring capabilities are exceedingly good, and the performance of the vehicle at the War Office trials was highly successful.

Dr. Brightmore's steam lurry, built by the Coulthard firm at Preston, is shown in side elevation by Fig. 593 and in plan by Fig. 594; front and end views (boiler removed) are given by Figs. 595 and 596. Its special feature is its system of driving with the front steering wheels, and steering by varying the speed of those wheels. The whole of the driving mechanism is mounted upon an under-carriage supported by springs A, above the front axle and connected to the main frame by a central universal joint B. A claw-shaped slide block is carried by the under-carriage in a line immediately behind the ball joint, and slides upon a circular guide G, fixed beneath the main frame, the claw being free to swing about a horizontal pin which is at right angles to the front axle. The guide prevents the fore-carriage from tipping either way about the front axle, but allows it to turn about the ball joint in a horizontal plane and to assume an independent position in a transverse vertical plane relatively to the main frame. The Coulthard standard compound motor (p. 100) drives a differential counter-

Fig. 591.

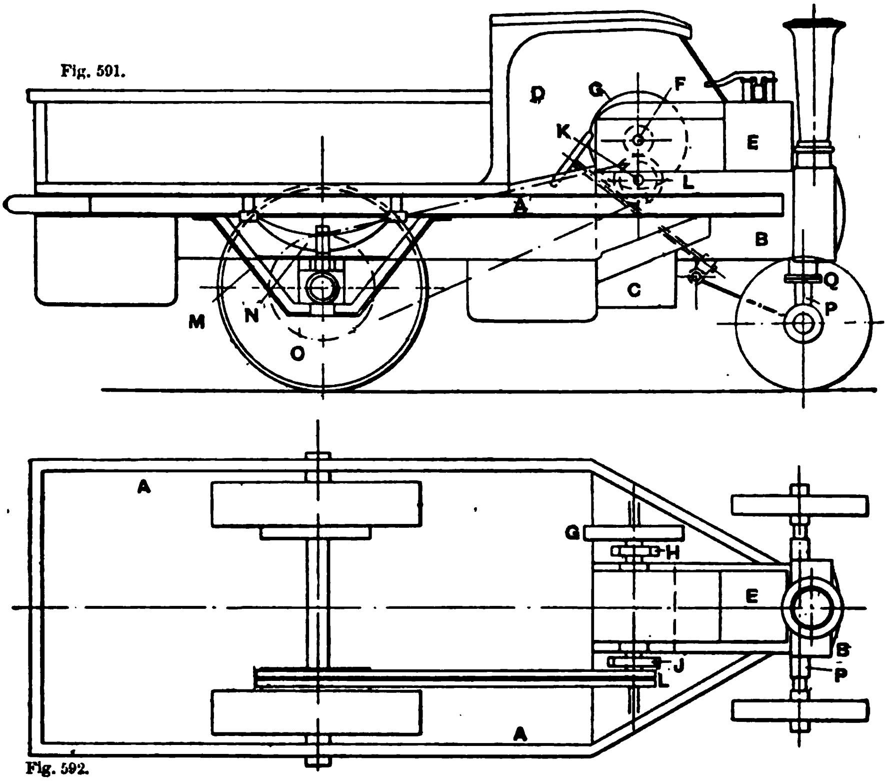
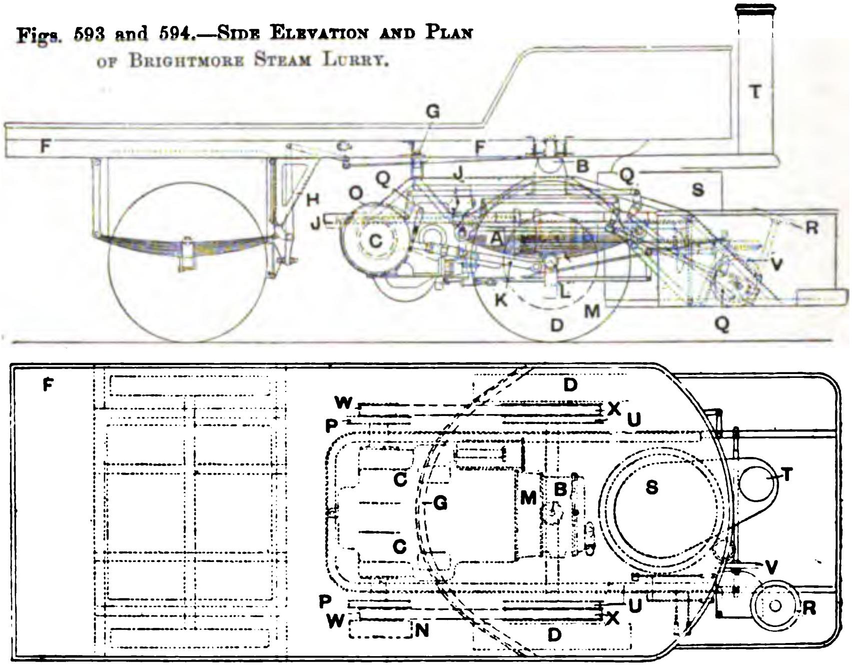


Fig. 592.

Figs. 591 and 592.—Elevation and Plan of Foden Steam Lurry.

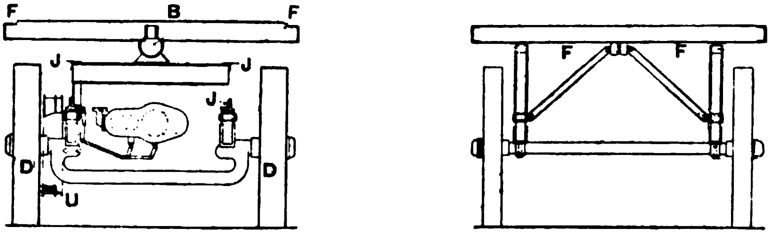
shaft C, from which the front wheels D are chain-driven, there being means of retarding either wheel and accelerating the speed of the other, so giving the vehicle a circular course for steering purposes. To prevent irregular road surface, etc., affecting the sensitive steering, friction is introduced between the two parts of the differential shaft. To describe the vehicle in detail, the channel steel main frame F, Figs. 593 to 596, carries the platform and one part of the ball joint B, semi-circular guide G, downwardly projecting brackets H, and a 800 litres (175 gallons) water tank over the rear angle. The fore-carriage angle steel framework J, supported by springs A, carries two cross channels, to which is bolted the lower part of ball joint B, and it also carries a cross channel supporting the horizontal pin which secures it to the sliding clip riding about the curved guide G. The ends of the springs are secured to V blocks, which slide freely upon guide surfaces on the

Figs. 593 and 594.—Side Elevation and Plan of Brightmore Steam Lurry.



underside of the fore-carriage frame. Adjustable distance rods K pass from the front axle L to the bearings of the differential countershaft C. It will be seen that the entire fore-carriage can turn freely about the ball-joint B horizontally, and that the circular guide G keeps its horizontal centre line parallel with the main frame, but that the carriage can conform to road surface irregularities without imposing a twisting strain on the main frame. The motor M and mechanism are enclosed in an oil-tight casing fixed to the lower member of the fore-carriage so that the cylinders lie above the front axle; the two horizontal cylinders are of 101·6 mm.

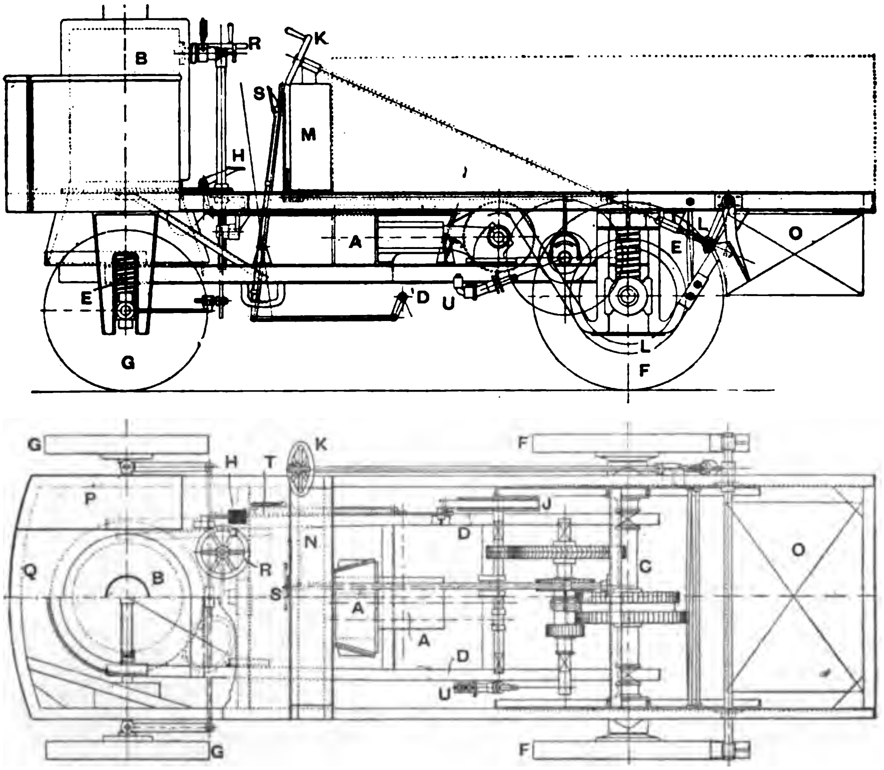
and 177·8 mm. (4 in. and 7 in.) bore respectively, and the stroke is 15·24 mm. (6 in.). The countershaft C carries at its right end a special friction device N, which compels the road driving wheels D to revolve at the same speed in spite of any tendencies which the road may have to cause one to turn more than the other. The steering band brakes O on the differential shaft consist of a steel wire cable carrying gun-metal friction blocks encircling each brake drum P, and are operated through levers Q from the steering wheel R. Thus, to turn the car to the right the right-hand brake is applied, the degree to which the direction of the car is altered depending on the degree of pressure applied to the brake; that is, it depends on the difference between the speeds of the two driving wheels. The boiler S is placed between the fore-carriage and platform (see p. 41), and its funnel T is connected with it by a horizontal extension of the smoke box. Opposite the steering wheel to the left is a bunker holding nearly 200 kg. (4 cwt.) of coke. Band brakes U on the driving wheels are of the same type as those on the differential shaft; they are worked by the hand wheel V. They are carefully compensated; otherwise, if one brake became more worn than the other, application of the brakes would tend to deflect the lurry from its course. The sprockets W drive sprockets X by Renolds silent chains. The whole platform area, measuring 4·87 m. by 198 cm. (16 ft. by 6·6 ft.), is available for goods (1 load is 5 tons), the driving mechanism being entirely beneath, and the fore-carriage projecting to a short distance only in front of it. The wheels are 104 cm. (3·5 ft.) in diameter, the wheel base is 244 cm. (8 ft.), and the front and back tyres are 17·8 cm. and 15·2 cm. (7 in. and 6 in.) in diameter respectively. The vehicle can turn completely round in a road 9·14 m. (30 ft.) wide.



Figs. 595 and 596.—Front and End Views of Brightmore Lurry.

Jesse Ellis and Co.'s steam wagon (Figs. 597 and 598) has a 25-h.p. horizontal two-cylinder compound motor A, working normally at a pressure of 14 kg. per cm. (200 lb. per sq. in.). It has an injector and pump. The boiler B is in front, as in the Thornycroft lurry, and is centre-fired, the fuel being coke: it is of the water-tube type, the ends of its 142 water tubes ending in a special water jacket, which counteracts any tendency to leakage. The motor drives the differential of the live rear axle C by means of a two-speed spur gearing, giving 4·8 km. and 9·6 km. (3 and 6 miles) per hour; speed can be changed only while stopping. The traction engine device of locking the differential so as to drive the two rear wheels together when in difficulties is employed, a special key being inserted through the hub of one of the wheels, and so locking it to a shaft which is solid with the opposite half of the live axle, the wheel in question running in reality on a sleeve. The whole structure of the vehicle is, to a certain extent, on traction engine lines. The motor and gearing, however, are mounted in a separately slung underframe D, with the object of reducing vibration and shock, the vehicle itself being mounted on powerful spiral springs E, arranged in guides over the bearings. The vehicle is 4·87 m. long by 198 cm. wide (16 ft. by 6·5 ft.), and is built to carry 4 tons, whilst on fairly level roads it will in addition haul a trailer carrying 2 tons. The driving wheels F are 107 cm. (3 ft. 6 in.) in diameter, and the front wheels G 91·4 cm. (3 ft.) in diameter. The pedal H operates band brake J and the wheel K operates side brake L. M is a water tank under the driver's seat N; O is the rear water tank, P the coal bunker, Q space for condenser, R the hand steering wheel, S the speed-changing lever, T the reversing lever, and U the feed pump.

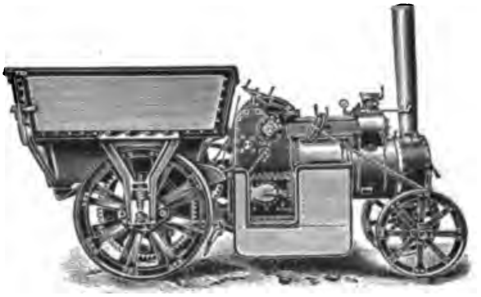
The Mann steam cart is shown by Fig. 599, p. 538, and its construction is more easily understood by reference to Fig. 600, p. 538, which is a section through the rear axle. The motor is fixed upon the top of the boiler, and the crank shaft carries a pinion wheel at each end and a fly-wheel outside the pinion on the left-hand side. A first countershaft lies parallel with, but below and behind, the crank shaft; and two spur wheels are so arranged upon this countershaft that either the one or the other of them can be brought in gear with its corresponding pinion on the crank shaft. A second countershaft is driven by the first one, and it in turn drives a large spur wheel A (Fig. 406), upon the differential gear. A band brake acts upon a drum on this countershaft. The rear axle B, of 8·9 cm. (3½ in.) diameter, passes from the left-hand driving wheel C, which is fixed to it, through the right-hand wheel D to an outside thrust collar. The bevel wheel E of the differential is fixed to it on a squared portion, and the bevel wheel F, with its right-hand driving wheel, runs freely upon it. The bevel F has a brake drum, and



Figs. 597 and 598.—Side Elevation and Plan of Ellis Steam Lurry.

the spur wheel A carries a divided brake band (not shown), which can be tightened so as to lock the differential gear when desired. The cart body G is carried by hornplates H upon its own wheels I, and these wheels can be pinned rigidly to the driving wheels D by the bolts J. The wheels are each built up of two steel plates K, flanged at their peripheries, bored out at their centres, curved as shown in Fig. 406, and cut out so far as to form strong spokes. These plates are connected together by a central cast steel boss or hub L, to which they are riveted, and by a wide steel tyre, which is similarly fixed in place. The wheels D are so made that

Fig. 599.



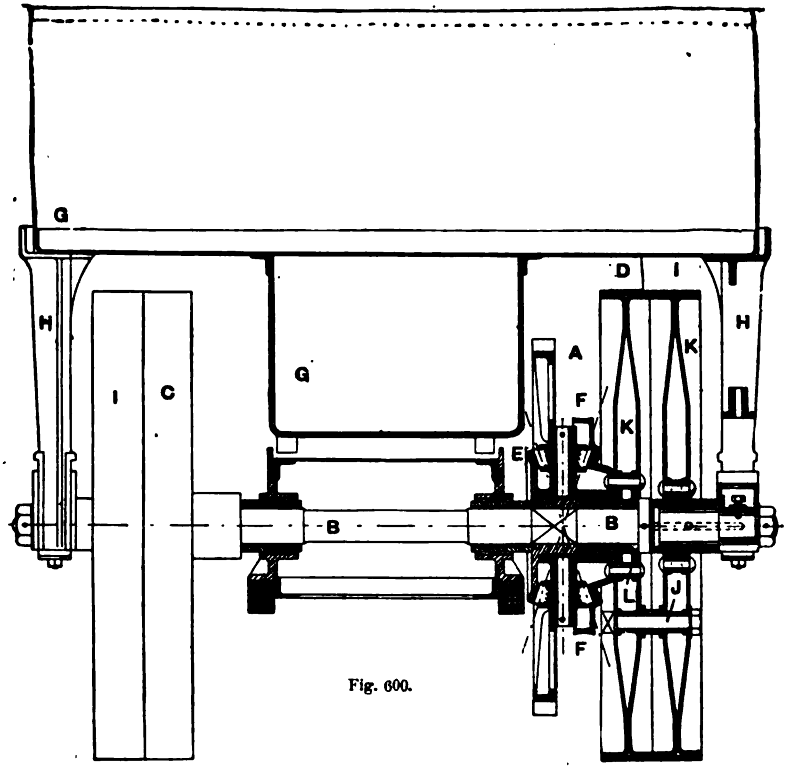


Fig. 600.

Fig. 599.—Mann Steam Tipping Cart. Fig. 600.—Half Back Elevation and Half Section of Mann Cart.

the pins J pass through specially provided portions which come between their ordinary spokes; but in the wheels I the pins pass through the centre of the spokes; by this arrangement the strength of the double wheel is increased in consequence of the spokes of the inner and outer wheels failing to come opposite each other. The wheels are 4 ft. in diameter, and each single wheel weighs about 5 cwt. and is 5 in. wide.

In the Mann steam lurry, Fig. 601, the motor is fixed above a large water tank, formed by the frame between the boiler and the driving wheels. The crank shaft carries a pair of pinion wheels on its right-hand end. Either of two corresponding spur wheels on a countershaft can be brought into gear with one of these, and the countershaft drives the large spur wheel upon the differential gear. The motor, which is fitted with an oil bath casing, can be easily got at, when required, by tipping the balanced lurry about its stub axles. The rear axle and the driving wheels are very similar to those above described, except that the latter are 3 ft. 6 in. in diameter. The sides of the framework are made in one piece with the side plates of the fire-box, and the bearings are made to register accurately into these plates; long bronze bearing surfaces are provided for the crank and countershafts, and these are supported in steel castings which are bolted to the frame, as well as being turned to fit the holes bored in it. The front axle is mounted centrally in hornplates, and is fitted with a transverse spring; the whole of this is carried by a turntable beneath the boiler, and steering is effected by a sloping hand-wheel and through worm gearing. Both cart and lurry employ very simple reversing gear.

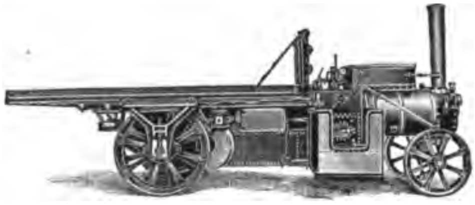
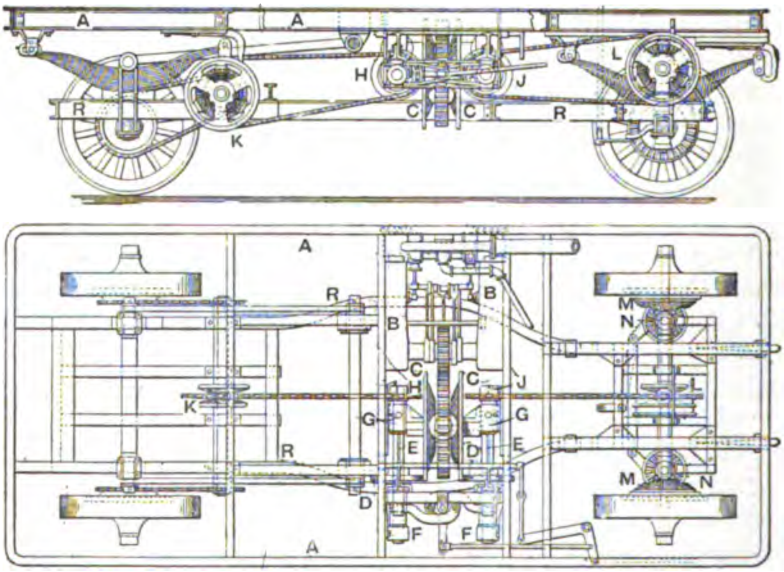


Fig. 601.—Mann Steam Lurry.

In the Aultman steam lurry (American), power is applied to each of the four road wheels; Figs. 602 to 604 show the vehicle in side elevation, plan, and end elevation. The end elevation is drawn to twice the scale of the other figures. The lower of the two frames R carries part of the transmission gear and connects the two axles, whilst the upper frame A forms the frame of the lurry proper, and supports the driving mechanism. The 16 h.p. two-cylinder motor B has a bore and stroke of 114 mm. (4·5 in.);

its shaft drives by spur-gearing a central differential gear C whose side members have smooth discs, against which press the friction wheels D. These are mounted on the shafts E carried in brackets having bearings F G. Shafts E are capable of a certain amount of swing to enable the friction wheels D to be brought into contact with or removed from the discs C. The friction wheels D also can be moved along the shafts E nearer to or further away from the centres of the friction discs. This



Figs. 602 and 603.—Side Elevation and Plan of Aultmann Steam Lurry.

gives a progressive change of speed. The shafts E each carry a sprocket wheel, H J; the rear sprocket H chain-drives the differential K on a rear countershaft, which chain-drives the rear road wheels; the distance rods maintain the chains uniformly tight. The sprocket wheel J drives differential L on the front countershaft above the front steering axle; this shaft transmits power through bevel wheels M, N, and P to bevels Q, fixed to the steering wheels. Bevel wheels N P are mounted on vertical shafts O, which form the steering heads. The Ackermann principle is adopted, and the driving bevel wheels permit of the necessary movement. The differential gear C permits of a difference of speed between the front and rear axles when necessary. Transmission of power by frictional devices is always unsatisfactory, and in this case necessitates a system of interlocking levers by which the shafts E are moved so as to disengage the wheels D when they are to be moved along the faces of the discs C, and also springs acting on the ends of the shafts to bring the back into the position of engagement. This complication is unsatisfactory, and the whole method of changing speed appears uncalled for, more particularly in combination with a flexible steam motor. The boiler is of the vertical fire-tube type, and the burner consumes petrol spirit. The lurry is intended for loads of 5 tons, and has a platform space of 182 cm. by 365 cm. (6 ft. by 12 ft.).

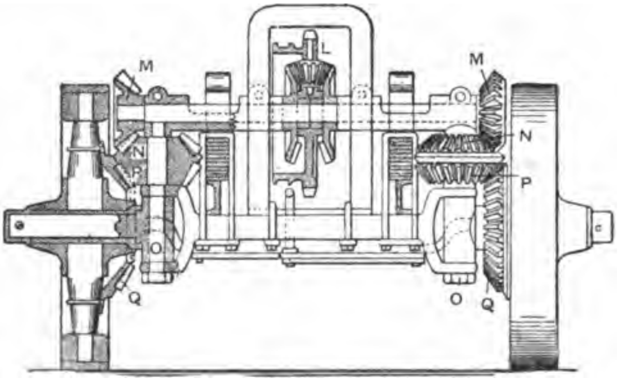


Fig. 604.—End Elevation (enlarged) of Aultmann Lurry.

The Morgan steam lurry (American) has its boiler and motor over the front steering axle. The water-tube boiler has a steel steam-dome connected to the mud drum at the base by 120 curved or twisted tubes. Above the dome, a cylindrical superheater projects up into the chimney, and is heated by waste gases. The boiler is tested to 42 kg. per cm.^{2} (600 lb. per sq. in.), and it is said that 90 kg. (200 lb.) of steam can be raised in 20 minutes. The petroleum is vaporised in a device resembling the Lifu burner (p. 55); the construction of the boiler and motor is on Lifu lines. The two-cylinder compound motor has a 127 mm. (5 in.) stroke, the cylinder bores being respectively 176·2 mm. and 152·4 c.m. (3 in. and 6 in.). The interiors of the cylinders are not lubricated directly, and this allows of condensing the exhaust steam and using the water again without special precautions. When necessary, live high-pressure steam can be admitted into the low-pressure cylinder, and the power greatly increased. The lurry frame is of 10 cm. (4 in.) channel steel. The drive is by a longitudinal shaft and bevel gearing on to a differential counter-shaft, and thence by steel pinions on each end of the shaft to bronze gear rings secured to the road wheel spokes. All the gear wheels are enclosed, and the differential can be locked when required.

The Spencer steam delivery wagon for transporting light goods upwards of half a ton in weight is an American vehicle with a closed-in body, water-tube boiler, and a 6 h.p. four-cylinder single-acting motor. The boiler has 8 shells of water tubes, each having a circulating coil surrounding it, the shells being joined together at top and bottom; the heating surface is 4·18 m.^{2} (45 sq. ft.), and it measures 56 cm. by 30·5 cm. by 46 cm. high (22 in. by 12 in. by 18 in.). The motor cylinder bore is 52 mm. (2·5 in.), the stroke 101 mm. (4 in.), and the working pressure 10·5 kg. per cm.^{2} (150 lb. per sq. in.). The petroleum fuel (ordinary lamp paraffin) is supplied to the burner under air pressure. A float-feed mechanism controls the water feed to the boiler; an aluminium float in a vertical supply pipe rises when the required level is reached and cuts off the supply, as in a float-feed carburetter (see Chapter V.). There is a steering side lever, a band brake on the differential, and a block brake on the wheel tyres. The frame is of angle steel, and the wheel base is 183 cm. (6 ft.) and the tread 142 c.m. (4 ft. 8 in.). A copper tank carries 182 l. (40 gal.) of water, and a steel tank 45·4 l. (10 gal.) of petroleum.

The Le Blant tractor (Fig. 605) is intended to haul an omnibus carrying 15 to 20 passengers or a van carrying 5 to 6 tons. It has a flash boiler with a heating surface of 15 m.^{2} (161 sq. ft. 66 sq. in.) and a 20 to 30 h.p. motor (p. 83). The latter is placed horizontally above the underframe, between the two axles, and drives the rear axle by aid of a pinion mounted at the crank shaft, an endless chain and a toothed wheel forming one with the differential. The steering is operated by a pivoted fore-carriage, whose lower hoop is toothed for one-third of its circumference and worked by an endless screw. The main frame is of U-steel, assembled by means of squares and angle plates riveted hot, and it rests on the axles by springs placed outside the wheels as with wagons; the small diameter of the wheels and the general structure have somewhat the appearance of a goods van. The weight of the tractor, ready for the road, is 7·5 tons, including 650 kg. (1,430 lb.) of water and 250 kg. (550 lb.) of coke; necessarily the weight is considerable, because part of it is used to increase the adhesion. The hauled car has not a single axle like that coupled to the de Dion-Bouton tractor; it has the shape, according to the circumstances, of a goods van or a tramcar. Carrying 20 passengers, it weighs 4·7 tons, and the tractor hauls it at the rate of from 10 km. to 30 km. (6·2 miles to 18·6 miles) per hour. Le Blant has also constructed a less heavy tractor than the preceding, weighing, ready for the road, 4 tons; it is driven by a motor of 15 to 20 h.p., and ascended the gradient of Grand-Jonc at Issy at the rate of about 15 km. (9·3 miles) per hour, hauling an omnibus which seated 15 persons.

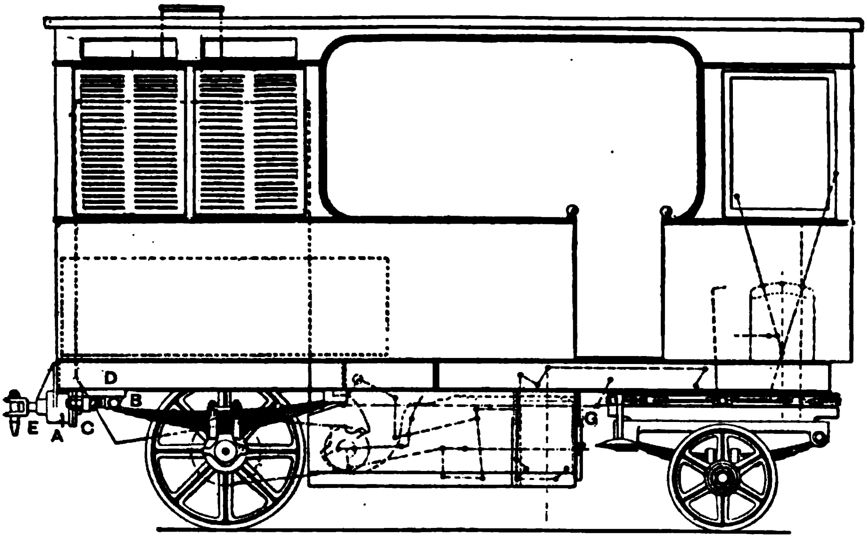
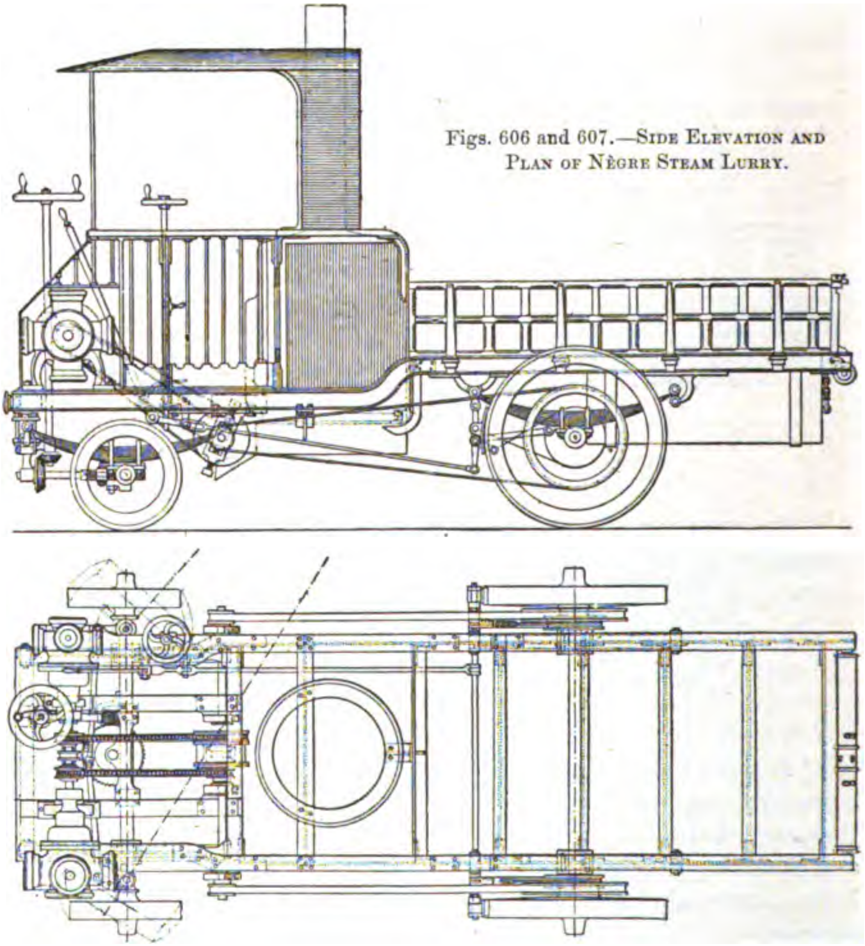


Fig. 605.—Le Blant Steam Tractor.

The Nègre lurry (Figs. 606 and 607), is constructed to carry a useful load of a ton; the boiler (p. 52) is multitubular, and there are two Nègre motors (p. 92) of different dimensions, so as to be able to work compound or separately, and thus give 10 or 16 h.p. Boiler and motors are in front of the lurry. The driving shaft performs 400 or 500 revolutions per minute, and drives through two chains and sprockets the differential shaft, which communicates motion to the rear driving wheels by chains, whose tension can be regulated by angular displacement of a device seen behind the steering fore wheels. The two speeds are 8 km. and 16 km. (4·9 miles and 9·8 miles) per hour. The Lemoine brake is coiled on the rear axle or on the differential shaft, and it is worked by a pedal. Another pedal works a shoe brake, which can be kept tight by means of a screw. The main frame, made of angle iron, rises at the back of the motor and boiler platform to receive the floor of the lurry. The water is carried in a tank of 600 l. (132 gal.) capacity.



Figs. 606 and 607.—Side Elevation and Plan of Nègre Steam Lurry.

Hitherto in this chapter only powerful vehicles arranged for carrying a useful load of a ton and more have been described, and it must be remembered that steam is particularly suitable for traction of heavy weights. By substituting petroleum or petrol spirit for coke and inventing a new boiler, Serpollet was able at once to do away with the dust associated with coal and coke, and with the necessity of having an engine attendant, thus rendering steam applicable to light cars. This is demonstrated by a study of the remarkable car which he exhibited at the Tuileries in 1898. This phaeton, weighing 500 kg. (1,100 lb.), had a 5-h.p. motor, which, together with the boiler, was at the back of the car, the motor resting directly on the axle.

Light steam cars have the choice of four types of steam generator, fire-tube, water-tube, flash and semi-flash; and cars employing these will be described in this order.

Certainly the best known light steam car is the Locomobile, which is of American manufacture and bears the stamp of its origin in the design of every part. The cars that have been on the market for a number of years are mostly of the 5½ h.p. type, and their distinctive features have been (*a*) the employment of a fire-tube boiler 35·6 cm. (14 in.) in diameter, containing 290 copper tubes; the copper shell is wound round with steel wire, and the ends of the boiler are formed of steel tube plates; (*b*) a burner consuming petrol spirit, and started by heating with a torch, the fuel supply being regulated by an automatic diaphragm valve which is set to shut off the fire at the desired steam pressure; (*c*), a double-acting steam motor with simple link reversing gear, and driving a feed water pump, the fuel feed to the boiler being governed by a bye-pass valve hand-controlled by the driver; (*d*), an auxiliary water feed hand pump; (*e*), a tank in which the petrol spirit is carried under a pressure whose constancy is maintained by means of air tank and hand pump; (*f*), simple chain transmission to a live rear axle; (*g*), wire wheels and a light body typically American, and (*h*) tiller steering. The modern cars respectively of 5½ h.p., 6½ h.p., and 10-h.p. agree in general with the above brief summary, but the highest-powered of these cars is more strongly built, the road wheels are of the artillery type, there is a number of refinements all conducing to the more efficient working and easier control; steering is by wheel or tiller, and the burner is not started with a torch. Two examples of the lower-powered and lightly constructed cars are illustrated in Figs. 608 and 609. The 10-h.p. cars are here chosen for description. The dos-à-dos has wheel steering, but another type—a four-seat Surrey—retains the tiller system.

The Locomobile 10-h.p. dos-à-dos has a wooden main frame, and the boiler is carried by steel cross tubes, the front one of which has bearings bolted to it for receiving the motor. The steam and exhaust pipes leading from the cylinder casting form trunnions for supporting the engine in place, and fit into the bearings just referred to. The motor is of much the usual type, having two double-acting high pressure cylinders which are lagged outside and enclosed in a metal casing; the bore is 76·2 mm. (3 in.), and the stroke 101·6 mm. (4 in.). The crossheads have large rollers sliding in grooved guides, and the connecting rods have roller bearings at their big ends, the crank-shaft being carried in roller bearings in the motor frame. The reversing gear is of the link-motion type, and the slotted quadrants are thrown over by a projecting lever connected with a hand lever on the right-

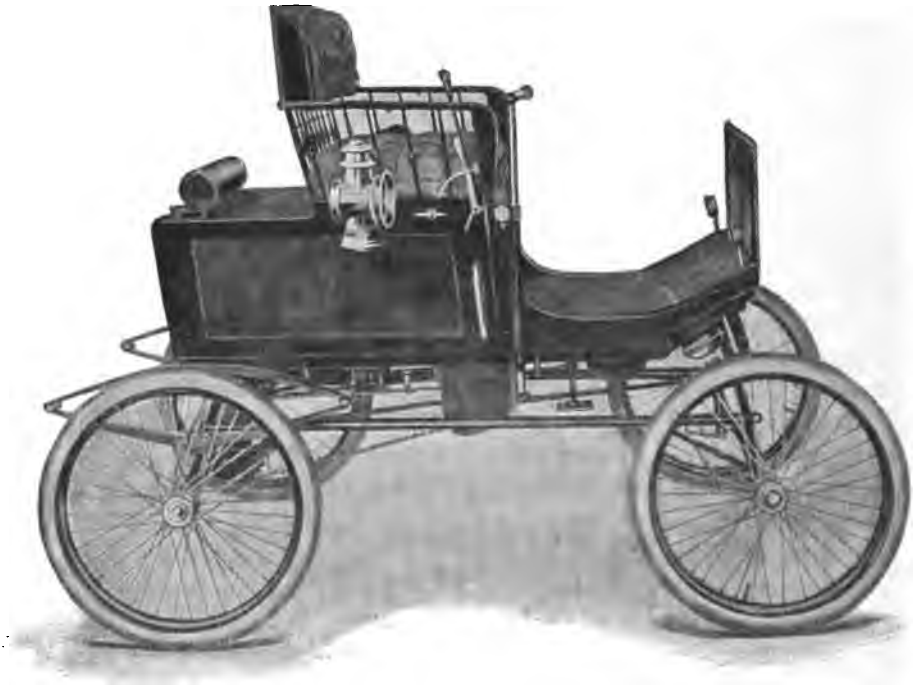


Fig. 608.—Locomobile Two-seat Steam Car.

hand side of the body. All the small parts are made from steel drop forgings, and the bearing surfaces are of ample dimensions. The driving sprocket is fixed centrally on the crank-shaft, and a roller chain passes from it to the sprocket on the live rear axle. The aluminium crank chamber is in four pieces, one of them having a hinged inspection door. The feed water pump is bolted outside the crank chamber upper casting, and is operated by a swinging lever pivoted to the bracket holding the pump, and is connected at one end to the plunger and at its inner end by an intermediate rod to one of the crossheads. The piston rods and the valve spindles pass through stuffing boxes fitted with projecting levers ; small ratchets are fitted between the levers and the stuffing boxes so that the packing in the latter can be tightened up without employing a spanner for the purpose, by merely moving the levers backwards and forwards. The motor is secured in place by the steam and exhaust pipe fittings forming trunnions, and by a distance rod which connects the crank chamber with the back axle. The motor is lubricated entirely by the Locomobile octopus lubricator fixed above the cylinders. The boiler is of the type mentioned in the previous paragraph, its diameter being 40·6 cm. (16 in.), and its copper fire tubes numbering 340. The burner has two vaporising tubes passing over and across it from

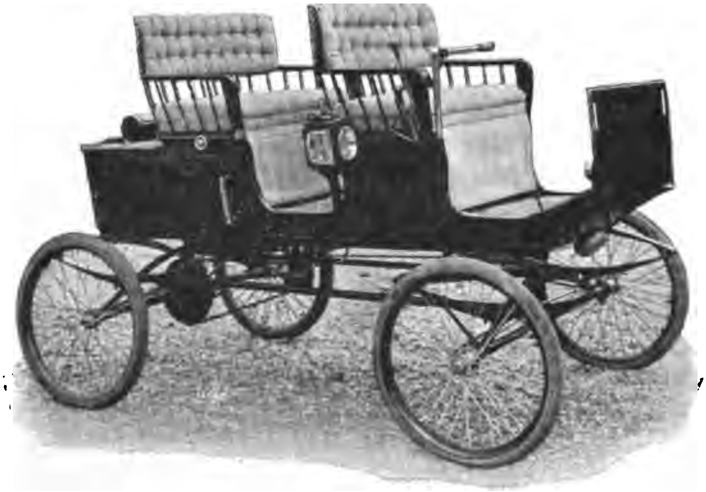


Fig. 609.—LOCOMOBILE FOUR-SEAT STEAM CAR.

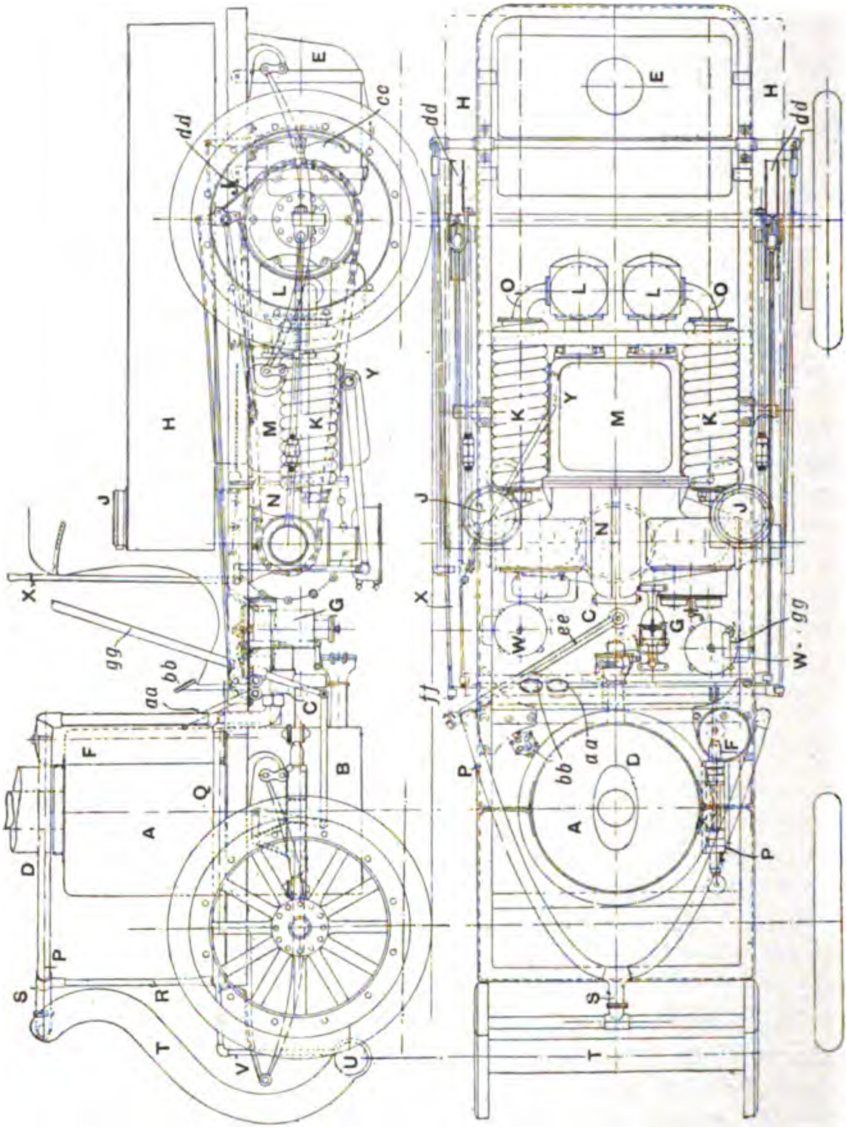
the starting heater box; at the other end they are joined together by a connecting piece, and by means of removable plugs the tubes can be cleaned out without being disturbed. The starting arrangement is a box containing a small vaporiser tube heated by a petrol lamp. The burner is fitted with the usual diaphragm valve, which is connected with the steam pressure in the boiler through a pipe. The valve does not entirely shut off the petrol feed, but allows a certain minimum quantity to flow past it so as to provide a pilot flame. The casing into which the burner fits down is so made as to take in the air supply at the side instead of at the bottom, thus avoiding any risk of blowing out in a high wind. The differential gear on the live rear axle is well designed. It contains four planet pinions and two large bevel wheels, and the driven sprocket registers over and is bolted to one half of the shell. The live axle is carried in four roller bearings, one near each end of each shaft or half axle. The shell of the differential forms two brake drums, one on each side of the sprocket wheel, and brake drums are also fixed to the hubs of each wheel; altogether there are four double-acting band brakes.

The steam air pump for maintaining pressure in the air and fuel tanks, and the steam water pump are placed horizontally beneath the floor in front of the driver's seat, and either can be brought into use by moving a small lever just behind the dash to the right or to the left, when the pressure in the fuel tank will be increased, or water will be forced into the boiler. The steam air pump allows a greater quantity of petrol to be carried, because the air tank may also be filled with petrol, and yet the pressure upon the fuel can be maintained without much trouble to the driver. Although the pressure on the fuel will soon begin to fall if both tanks have been filled, yet the steam pump need be brought into operation only occasionally to renew the pressure. This pump can also be used for inflating the tyres. The steam water pump restricts the use of the hand pump to those times at which there is no pressure in the boiler. The speed of the car normally is regulated by the throttle valve, and this is controlled by a small horizontal lever on the steering pillar. The reversing lever moves over a quadrant provided with three forward notches and one reverse notch. The boiler is fitted with a superheater of the Strickland form, placed between burner and boiler, the steam being led through it on its way from the boiler to the throttle valve. The superheater is made out of steel tubing, and although only about

183 cm. (6 ft.) long effects an economy both of water and of petrol of about 25 per cent. The water gauge is of the Klinger pattern. The petrol tank holds about 41 l. (9 gal.), sufficient for a run of about 88 km. (55 miles), and the water tank holds 127 l. (28 gal.), sufficient for about 48 km. (30 miles) run. The wooden wheels are 71 cm. (28 in.) in diameter, and have 76·2 mm. (3 in.) Fisk pneumatic tyres. The wheel base is 203 cm. (6 ft. 6 in.), and the track is 137 cm (4 ft. 6 in.).

The Chelmsford car is made by Clarkson and Capel; generally it is fitted as a private omnibus or long distance touring car, and line drawings representing elevation and plan are given by Figs. 610 and 611. The rectangular main frame is of channel steel. The fire tube boiler (p. 43) is shown at A, its burner (p. 44) at B, and the starting lamp at C. The oval-section funnel D passes through the roof, and on either side are curved glass window panes opened or closed at will. From the main oil tank E at the rear, oil is pumped to the pressure chamber F, mounted behind the boiler on the left; sufficient fuel is carried for 193 km. (120 miles), the consumption being ·75 l. (1·33 pint) per car mile. Oil flows from tank F through a stop-cock to the burner, which is regulated by an automatic device G (*see* p. 44). The water tanks H are hidden beneath seats; altogether they carry 154 l. (34 gal.), which lasts just as long as the fuel oil, and they have removable covers J, and a special funnel containing a gauze strainer. The water is pumped from tanks through two heaters K to the boiler. The 12-h.p. two-cylinder, double-acting motor with cylinders L (*see* p. 84), is fixed horizontally below the frame; the crank chamber M and a separate casting forming the crank-shaft bearings are bolted to casing N, which encloses the differential gear and transverse countershaft (*see* p. 367). The drive is by spur gearing to the countershaft, and thence side chains to the rear wheels.

The exhaust steam from the motor is taken by two separate exhaust pipes O to the feed water heaters K, which are wound externally with wire to assist in cooling the exhaust steam. The steam then passes to the opposite ends of the tube P, which forms the top of a V-shaped cooler surrounding the closed-in front portion of the car. This radiator resembles a V in the plan view; the top and bottom tubes P Q are connected by vertical wire covered tubes R. A certain amount of steam flows into them, and is thus condensed, but the bulk of the steam flows through the connecting pipe



Figs. 610 and 611.—Side Elevation and Plan of Chelmsford Steam Car.

S into an **S**-shaped condenser, T, which has a large number of horizontal tubes. The condensed water in both coolers finds its way into the drum U at the lowest point of the system, the water from the **V**-shaped cooler passing down the pipe V. Any uncondensed steam is led into the flue above the boiler, so that it passes invisibly away through the funnel. The condensed water itself is pumped from the drum U through the filters W (part of it going through each), into the sponge box in the right-hand water tank. This sponge box, immediately beneath the front cover J, forms a kind of syphon; the sponge chamber itself is an open-ended vertical cylinder mounted inside a second chamber, closed at the bottom, but perforated near its upper end.

The side hand-lever X is connected with the valve gear by a system of levers, and operates it through a rocking shaft Y, lying across beneath the crank chamber of the motor; when this shaft is rocked it operates the reversing gear. The lever X carries a notched quadrant which engages with a catch let into the body. It allows the driver to vary the cut-off of the engine when running in a forward position, and to reverse the direction of travel. The two pedals *aa* and *bb*, in front of the driver, are connected respectively with side shoe brakes *cc*, and side band brakes *dd*. The shoe brakes press upon the inside face of rims bolted to the wheels, and the band brakes upon drums rigid with the large sprocket wheels. Under usual conditions the motor itself also forms a good means of stopping the car, for if the throttle valve is closed, and the reversing lever is thrown over, the motor acts as a pump, and the retarding action is sufficient to stop the car upon even steep hills. The steering lever *ee* is hinged to an upright side pillar *ff*, the lower end of which carries a crank which is connected by the usual system of rods to the heads of the steering wheels. The steering lever can be thrown up out of the way when required. The Ackermann principle is employed. The hand-lever *gg*, on the left, near the dial board, is connected by a system of levers with a combined water and fuel pump. The two pumps face one another, and their common piston rod is operated by the lever *gg*; one forces paraffin from the main tank into the pressure tank when desired, and the other feeds water into the boiler when the car is standing. This car is one of the few in which a successful condensing system has been combined with a fire-tube boiler; there does not appear to be the slightest trace of oil in the feed water, and the presence of oil in the water tanks is inadmissible, except with a flash boiler. The special form of lubrication—graphite mixed with heavy oil—employed may have much to do with the successful working. The condensed water is drawn from the coolers through a strainer by the pump on the countershaft, and is then forced by it through the filters to the sponge box The steam from the boiler is carried through a gridiron, M-shaped superheater above the burner before passing to the throttle valve. The power and speed of the motor are regulated, as a rule, by the throttle valve entirely, but in special cases, such as when ascending steep hills, the cut-off is varied.

The Vapomobile is an English-built car on more or less American lines. The boiler is semi-flash or fire tube, as required, and the motor is two-cylinder, double-acting, high pressure. The burner may be fitted for petrol spirit or paraffin. The car frame is of drawn steel tubing, and on the lighter cars the road wheels are of the bicycle type with steel spokes, artillery wheels being used on heavier cars. There is a central chain drive on to the enclosed differential of the live rear axle. When the semi-flash boiler is employed, it is desirable to condense the exhaust steam, as any traces of oil left in the feed water after filtration do not affect the working of this type of generator. In an open vehicle the condenser fitted for this purpose is underneath the car, and on top in a covered one.

The Saracen runabout has a 40·6 cm. (16-in.) fire-tube boiler and a vertical two-cylinder motor. Double-acting brakes on the rear axle drums are controlled by Bowden wires. The burner consumes petrol spirit, but can, it is said, be readily adapted for paraffin.

The House or Lifu light car is made by the Steam Car Co., House's System, Limited. It is a well-built car having a 10-h.p. horizontal motor, closed in, with its working parts running in an oil bath; the cylinders are compound, but with the use of an intercepting valve both of the cylinders may be worked at high pressure when climbing steep gradients. The power is transmitted to the back axle by a steel pinion on the crank-shaft meshing with a bronze gear wheel on the outside of the differential gear case, all running in oil. The cylinder end of the motor is hung to the frame of the car by a double-ended ball joint, thus allowing free action of the back axle, while at the same time the machinery mechanically adapts itself to the movement of the axle. Two pumps are worked from the motor with a double-ended plunger, one being the main feed-pump, and the other maintaining the air pressure in the oil tank when the car is running. By means of an auxiliary hand feed-pump the fire-tube boiler (p. 42) can be filled when the car is not running, and there is a hand air-pump fixed to the seat for raising the air pressure in the oil tank when necessary. The burner uses ordinary paraffin oil. When steam is up the burner flame is regulated automatically by the pressure in the boiler, and can be turned out from the driver's seat. The copper fuel tank holds enough oil for from 95 km. to 130 km. (60 to 80 miles). The water tank holds sufficient for 48 km. to 64 km. (30 to 40 miles), according to the condition of the roads, and both fuel and water tanks have indicating dials. The steam, after leaving the motor, passes into an exhaust box and atmospheric condenser; the uncondensed steam then is taken into the smoke-box above the boiler and passes away invisibly. The water from the feed-pump is forced through a large coil of copper pipe in the cover of the smoke-box, and then into a mud separator in the boiler, the products of combustion being used to raise the temperature of the feed water before going into the boiler. A powerful brake, operated by the foot, expands two levers (shod with fibre) into a flanged disc fastened to each of the hind wheels; this brake works during either forward or backward motion. The reversing of the engine also acts as a powerful brake.

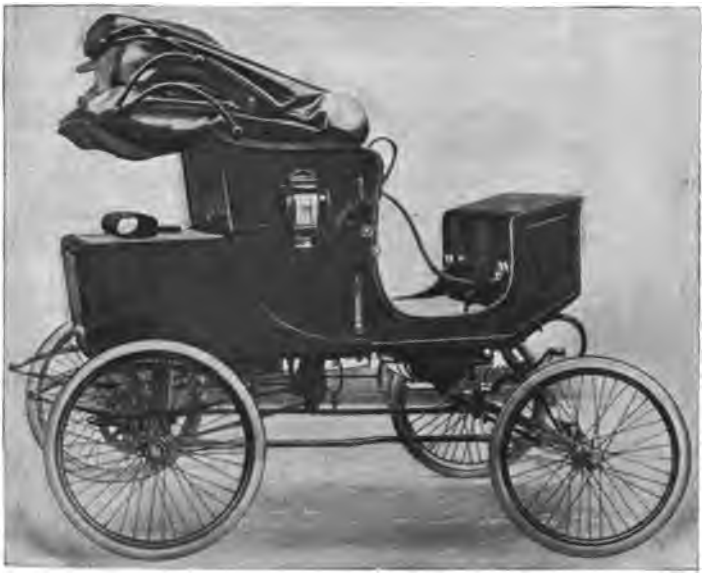


Fig. 612.—Weston Steam Car.

The Toledo steam car has the familiar appearance of an American runabout, but it weighs 680 kg. (1,500 lb.) and has a very strong tubular frame. The boiler is a special feature (*see* p. 57), as is the motor with its piston valves (*see* p. 85). There is the usual live rear axle, but this is made rigid by an arched tube passing over the differential. There is a tubular front axle. In front, the body is suspended above the underframe by two transverse springs joined together at their centres; the two ends of one spring are pivoted to the axle, and the other has its ends connected to a body. The rear springs are at the side. Other features are the use of a single lever for throttling and reversing, automatic lubrication, an arrangement of feed water heater combined with a silencer for the exhaust steam, and a steering tiller that forms a lever for operating an auxiliary feed water pump.

The Reading car has a 5¾ h.-p. four-cylinder, single-acting motor (*see* p. 92), and a multitubular boiler containing 365 tubes of 12·6 mm. (·5 in.) bore, with a heating surface of 5·1 m^2 (55 sq. ft.); both crown and circular shell of boiler are made from one piece of metal. The burner is of the usual American shape, but its feed pipe passes underneath the bottom plate, and so does not interfere with the perforation of the entire upper surface, or permit flooding. A steam water pump, steam air pump, water lifter, and condenser are fitted. A feature is the single hand control, consisting of a lever to the left of the driver, who sits on the left side of the car; the lever rotates a countershaft passing right across the car beneath the seat, the countershaft carrying cam plates which automatically operate the throttle valve and reversing gear. In the lever's central position steam is cut off, and movement one way admits steam for forward movement, and the other way for backward movement; further movement opens the throttle valve.

In the Weston steam car, automatic devices are not used, and the burner (p. 57) is started merely with a match. The fire-tube boiler at the back is described on p. 57, and the two-cylinder vertical motor under the seat, on p. 87. A new design is shown by Fig. 612. It has a somewhat stronger framework, springs, etc., than are usual in this type of car, and the seat and tread are wide. The box dash carries tools and petrol cans. A single roller chain connects the motor with the live axle differential gear, which is surrounded by a bridge (Fig. 613) which gives additional stiffness. The water tanks hold about 114 l. (25 gal.), sufficient for more than 48 km. (30 miles), and the petrol tanks hold sufficient for 120 km. (75 miles).

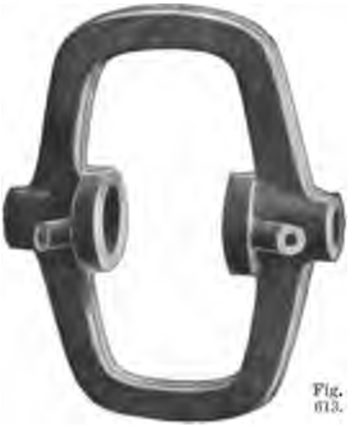


Fig. 613.

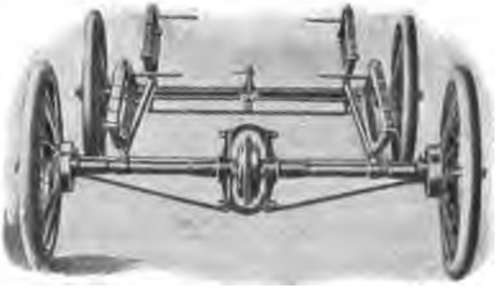


Fig. 614.

Fig. 613.—Weston Differential Bridge.
Fig. 614.—Prescott Steam Car Frame and Wheels.

In the Prescott steam car, whose undercarriage is shown by Fig. 614, the steam is superheated during its passage from the throttle valve to the double-acting two-cylinder motor, whose cylinder bore is 52 mm. (2·5 in.), and piston stroke 89 mm. (3·5 in.). The boiler shell of seamless steel is 40·6 cm. (16 in.) in diameter, and its top and bottom plates are connected by 367 copper tubes of No. 20 gauge, and 12·6 mm. (·5 in.) bore; a dry-plate is fitted inside and an outer asbestos covering is held in place by steel sheeting. The working pressure is 16·8 kg. per cm^2. (240 lb. per sq. in.). The special burner is described on p. 81. The steam is superheated after passing through the throttle valve by being led back to a coil placed between burner and boiler, the connecting pipes passing actually through two of the boiler tubes. Exhaust steam from the motor heats the feed water, and then passes to a neat condenser in front, formed of a large number of small parallel tubes expanded into end castings; for short runs, the steam is exhausted above the burner, where it is heated to invisibility. A steam feed pump supplies water to the boiler when the motor is at rest, and a smaller pump maintains the pressure upon the fuel tank. There is also a hand water pump. The front and rear axles are connected by reaches, as shown in Fig. 614, formed of steel tubes filled with ash. The four springs are elliptic. The drive is by a single chain to the differential, as usual in small steam cars. There is a peculiar form of band brake (*see* p. 492). The wheel base is 172 cm., and the tread 137 cm. (5 ft. 8 in. and 4 ft. 6 in.). The cycle-type wheels with steel spokes are 71 cm. (28 in.) in diameter. Empty, the car weighs 454 kg. (1,000 lb.). Two fuel tanks contain 34 l. and 11·35 l. (7·5 and 2·5 gal.) respectively, and 145 l. (32 gal.) of water can be carried.

The Stanley car has a horizontal motor beneath the boiler, and a spur wheel on the centre of the crank-shaft drives direct on to the differential gear of the live axle. The motor's moving parts are in a sheet-metal casing, and the crank-shaft and connecting rods have ball bearings. The burner resembles the Prescott (p. 81). Petrol spirit is pumped from the main tank and forced into a small pressure reservoir instead of being kept under pressure in bulk. The driver does not vary the cut-off of the motor.

One of the most interesting steam cars yet introduced is the Gardner-Serpollet, whose leading features—a flash generator and a novel superheated steam motor—are described on pp. 64 and 93 respectively. It is regretted that there is not space enough here to treat the many elements of this car in exhaustive detail; but the descriptions of the boiler, burner, and motor already given, together with the following description of the parts of the car and enunciation of the general principles on which it works, probably will meet most requirements. The carriage work is got up in several different styles, but the chassis is practically the same in all cases, and Fig. 615 gives some idea of it. A channel steel main frame supports at the rear the flash boiler which supplies superheated steam to the centrally placed motor, which, with the pumps driven by it, is also carried by the frame. A cylindrical oil tank lies across the frame, just in front of the motor, as illustrated, and the water tank forms the dash in front. On the left end of the motor crank-shaft is a sprocket wheel which chain-drives the differential on the live rear axle (*see* Fig. 357, p. 364), the speed gear ratio being about 3 or 4 to 1. At the other end of the crank-shaft is a spur wheel driving a stepped cam, which rocks a lever to which the fuel and water pumps are connected. Lubricating oil is contained in a reservoir alongside the motor, and is circulated by a force-pump; this is worked by a ratchet device driven from the end of the stepped cam shaft. The boiler steam pipe leads to a throttle valve from which pipes pass to each end of the motor. The condenser is formed of a number of horizontal tubes and is placed below the frame over the front axle, extending back as far as the cylindrical oil tank. A hand pump for initially feeding water to the boiler is fixed to the right-hand side of the frame and is connected with a hand lever at the side of the driver. Two regulating levers on the steering pillar respectively regulate the throw of the feed pumps and slide the composite cam which operates the motor valves (*see* p. 95); one lever regulates the quantity of water and fuel delivered to the boiler and burner, and the other varies the cut-off and reverses the motor. Pressing down a pedal to the left of the steering pillar opens the main steam throttle valve normally closed by a spring. To the right of the steering pillar is a pedal operating the rear wheel band brakes, and a strong side lever applies emergency spoon brakes on the rear wheels. Four pressure gauges, a relief valve, a small air pump, and two three-way cocks are fitted upon the dash board. As the steering pillar, carried by a light cross girder, is almost immediately over the front axle, the steering gear necessarily is somewhat unusual; the lower end of the pillar carries a pinion working on a quadrant; the quadrant is rigid with a shaft fitted with projecting arms from which two rods connect it with an independent vertical shaft, carried in bearings on the motor frame. From the lower end of this second short shaft an arm projects, and a connecting

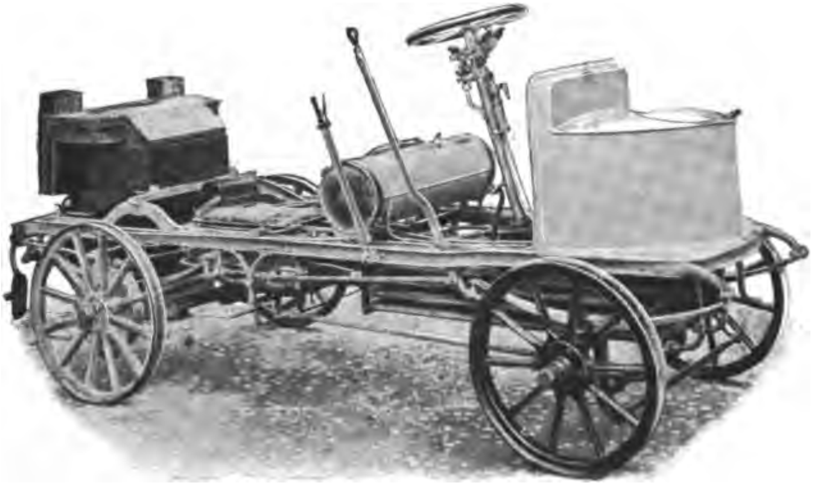


Fig. 615.—Gardner-Serpollet Steam Car Chassis.

rod leads from it to the steering head of the right-hand road wheel in the ordinary manner. A recent improvement is to couple the quadrant to the independent vertical shaft direct. The substantial live rear axle is carried in cast-steel axle boxes, in whose underneath oil boxes float small pieces of cork which keep the bearings oiled. The axle is solid from hub to hub, but sleeves connect each road wheel with the concentric planet bevel wheels of the enclosed differential gear; this differential is to the left of the centre, a short sleeve being free on the actual axle, and a long right-hand sleeve being solid with it. The road wheels slip over the actual axle and are driven by the sleeves through jaw clutches. The suspension springs are semi-elliptic, and the four artillery wheels are identical, having an approximate diameter of 91·4 cm. (36 in.), and being fitted with pneumatic tyres.

The diagram of water and fuel connections on the English Gardner-Serpollet cars (Fig. 616) shows also the device for starting the car without using the hand pump previously mentioned. The boiler is represented by a single zigzag tube; water is delivered into it at the lower end A, and the steam passes out through tube B. The burner is represented by four jets and is fed with fuel through pipe C, which forms a vaporising tube heated by the burners themselves. The combined water and feed pumps which normally feed the boiler and burner respectively are shown at the bottom of Fig. 616, and are operated by rocking lever D, which gives a reciprocating motion to pistons E and F proportionately. The dotted lines represent the different positions which the lever D assumes about its fulcrum. The water pump has a piston, E, suction valve, G, and delivery valve, H; and it normally draws its supply from the main water tank, through pipes I and J, and delivers this water through the pipe K to the connection junction L, and thence into the boiler tube at A. The fitting L has a non-return check valve, M, which permits the water to pass from the pump to the boiler, but prevents its return. The water pipe I branches in two directions as shown, the pipe N leading to a hand pump, O, which is worked by the driver by means of the vertical lever shown. The check valves of this pump are seen at P and Q. When this pump is brought into operation it delivers water from the main tank through pipe R into the same fitting, L, as does the power pump. Thus these two pumps constitute the ordinary water feeds apart from the self-starter described later. The superheated steam generated in the boiler passes along pipe B to a throttle valve situated at S. This throttle valve controls the flow of steam to the motor. On the boiler side of the throttle valve a branch pipe, T, leads down to a T-connection at the bottom of an automatic device forming a relief or safety valve. The T-connection forms a passage for the steam to the small piston U, and to the pipe V, which leads to the steam pressure gauge shown. This gauge indicates the steam pressure in the boiler at all times. The purpose of the relief valve is to prevent excessive

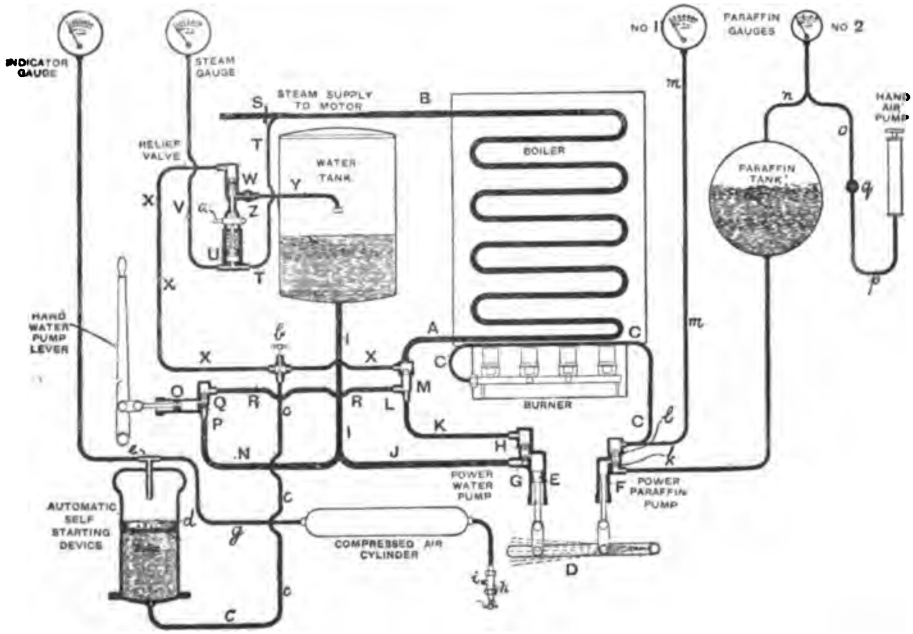


Fig. 616.—Gardner-Serpollet Steam Car Connections.

pressure in the boiler, and it acts as follows: The steam enters the small cylinder forming the lower part of the device, and when its pressure is sufficient it raises the piston U against the action of the inside spring shown; the piston rod then lifts the ball W off its seat with the result that the lower end of the boiler tube is in free communication with the water tank through the pipes A, X, and Y, past the ball W, and through the three-way cock Z, thus emptying the boiler of all water and steam. By means of a small hand-lever, *a*, on the relief valve, the driver can empty the boiler in a similar manner when desired. A valve, *b*, cuts off communication between the pipe

X and a branch pipe, *c*, but permits the driver to establish a connection between them without, however, closing the free passage through the pipe X itself. The purpose of *c* is explained below.

The English Gardner-Serpollet new self-starting device consists of a cylindrical container, called the "automatic self-starting device" in Fig. 616, in which is a piston, *d*, which separates water beneath from compressed air above it. The pipe *c* leads into the bottom of this chamber, and is full of water. The upper portion of the chamber, which is airtight, and sufficiently strong to withstand considerable pressure, is fitted with a T-piece, *e*, which communicates on the one hand through a pipe with a pressure gauge, and on the other hand through the pipe *g*, to a compressed air cylinder shown. This cylinder is connected with a fitting, *h*, which contains a valve arranged to open or close the connection between the cylinder and a threaded nozzle, *i*; When this apparatus is first fitted, an ordinary power pump is connected to the nozzle *i*; the valve in *h* then is opened, the valve *b* closed, and air is then forced into the compressed air cylinder and the container; in Fig. 616 the latter is called the "automatic self-starting device." The indicator gauge shows the actual pressure obtained. The valve in *h* then is closed, and the power pump removed. This, of course, is the procedure only when the device is first fitted. When steam has been raised in the ordinary manner, the valve *b* is opened, and a certain quantity of additional water is fed down the pipe *c* into the lower portion of the container, until the pressure of the air in the container is raised to that of the boiler. The quantity of water in the container will now depend upon the boiler pressure, and the water from it can be forced into the boiler only when the pressure in it is lower than that at which the relief valve comes into operation. Once having started, the valve *b* may remain open and the self-feeding device will work automatically and will only feed water to the boiler when the latter's pressure is less than that of the compressed air. If the throttle valve is closed, the pressure in the boiler will rise abnormally and the relief valve will open. At the same time the amount of water in the special container will have increased. The action of the relief valve then will allow only sufficient water to return to the main water tank to reduce the steam pressure to the required extent. During this time the water in the special container will return to its normal level, and if the motor is at rest the pressure in the boiler will prevent any more water from being delivered to it from the automatic device until opening the throttle again allows steam to pass to the motor. Ordinarily, therefore, as the valve *b* is open, it will not be necessary to use the hand pump O; but it is, however, very necessary that the valve *b* should be shut before the burner is extinguished, as otherwise the boiler pressure would diminish, and the water in the special container would tend to flow through it to the throttle valve S. When next using the car, and having heated up the boiler in the usual manner, the valve *b* may again be opened, and the hand-pump O need not be used.

With regard to the fuel connections of the English Gardner-Serpollet car, the paraffin tank is fitted at a higher level than the fuel feed pump (shown at the bottom of Fig. 616); this pump is smaller than the water feed pump, and its piston, F, has a shorter stroke than the piston E in consequence of its being attached to the lever D at a shorter distance from the fulcrum point. The power fuel pump takes its supply of oil through a pipe from the bottom of the paraffin tank. Its suction valve is at *k*, and its delivery valve at *l*. The delivery pipe from it branches in two directions, the one leading the oil through the pipe C and the vaporising coil to the burner, whilst the other communicates through pipe *m* with the paraffin gauge No. 1. As has been said, all the gauges are fitted on the dash in sight of the driver. No. 1 paraffin gauge indicates the pressure of oil in the burner, and enables the driver to guard against the two extremes of an extinguished burner and an excessive feed. The cylindrical paraffin tank is airtight and fitted at it highest point with a pipe, *n*, which communicates both with pressure gauge No. 2, and through the pipes *o* and *p* with a small hand air pump. This pump puts a small pressure upon the oil in the supply tank. Thus, when the motor is at rest, the pressure forces the oil past the check valves *k* and *l* to the burner, and thus maintains a sufficient flame. Two three-way cocks, *q* and Z, are shown in Fig. 616, the former fitted between the air pump and the fuel tank, and the latter in the water connections between the relief valve and the main water tank. The cock *q* firstly puts the hand air pump in connection with the paraffin tank; or, secondly, closes the end of the pipe *o*; or, thirdly, allows the air in the paraffin tank to escape through the cock itself direct to the atmosphere. The cock Z either establishes a normal connection between the relief valve and the water tank, or, secondly, cuts off this connection, or, thirdly, allows the water passing the ball W to escape direct through it to the ground. Thus cock Z may be made to show whether all is working properly. The description of the English Gardner-Serpollet car is now sufficiently complete.

The Chaboche steam car has as its principal features the employment of a new type of flash boiler (p. 69), a special burner (p. 70), a superheated steam double-acting motor forming one piece with the change-speed gear, a longitudinal driving shaft and live rear axle, and of automatic devices for regulating the feeds to burner and boiler. Fig. 617 gives a mere diagram of the general arrangement of the car, and shows chiefly the fuel connections. The channel steel main frame A supports in front a water tank, B, of sufficient capacity for 64 km. (40 miles), and suspended from it just behind the front axle is a condenser; behind the condenser is a fan worked by the motor. Motor and change-speed gear (p. 563) are enclosed in the aluminium casing C, fixed beneath the frame almost centrally between the axles. The fuel used is paraffin, and this is contained in the copper tank D, lying across the frame slightly forward of the back axle. It contains sufficient for 193 km. (120 miles). The boiler E, with burner F beneath it, is right at the back of the car (*see* p. 69). Water is taken from the main tank B through a small tubular cooler beneath it, and is delivered to a pressure drum, G, by a hand pump below the dashboard—this is but little used—or by a motor-driven pump. The drum contains a cushion of air and normally communicates freely with the boiler coils, so that water can flow between them either way. The pump delivery to the pressure chamber is regulated by an automatic device which bye-passes a certain quantity of the water back to the supply tank according to the steam pressure; this keeps the boiler pressure constant, because the water can be forced back from it to the pressure drum, whose pressure is indicated by a gauge. The boiler pressure can be increased by depressing a pedal which increases the effective strength of the spring that holds down the relief valve. The pressure chamber and boiler, between which is a shut-off cock, communicate through a coiled copper pipe, which being of thick metal stores up heat when water passes back through it to the pressure chamber, and gives up its heat when the water passes in the other direction. The paraffin for the burners F is drawn from tank D, and forced by a power pump into another pressure chamber, H, for which there is a gauge on the dashboard; the pressure in this chamber is kept constant by a spring-loaded relief valve which bye-passes oil back to the suction side of the fuel pump when the desired pressure is exceeded. The quantity of air forming the cushion in the chamber H is maintained, as it becomes absorbed by the oil, by a hand pump, J, on the steering pillar. The driver varies the actual pressure by means of a small handle, this varying the effective strength of the spring holding down the relief valve. The fuel flows to the burner from its pressure chamber H through a hand-regulated needle-valve, and an automatically controlled valve, K, mentioned on p. 69. Valve K cannot cut off the fuel supply entirely, and sufficient oil to keep the burner alight always passes. The steam passes through the expansion pipe which controls the fuel supply to a safety valve, and thence to a throttle valve controlled by a small lever on the steering pillar. A small pipe leads from the safety valve to a gauge on the dash, and forms a trap for any foreign matter. Two separate pipes take the steam from the throttle to the two cylinders of the motor. From the lubricating oil pressure chamber, L, the oil passes to the boiler, where it floats upon the water and is forced at boiler pressure to a lubricator and thence to the motor. The pressure of oil in the flash boiler does not affect the working.

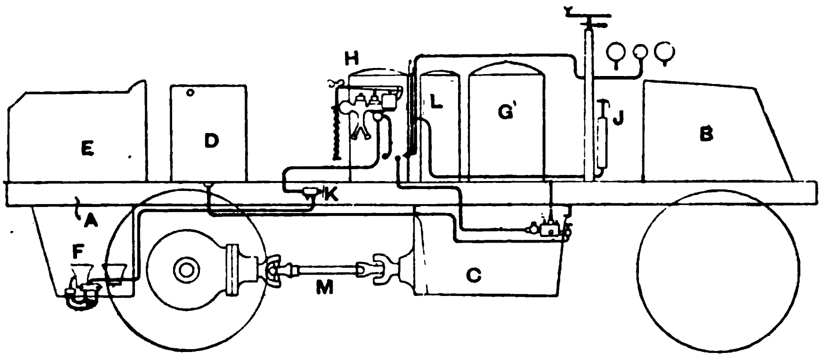


Fig. 617.—Chaboche Steam Car Fuel Connections.

The Chaboche superheated steam double-acting motor can hardly be considered apart from the transmission gear, as may be apparent from the diagram, Fig. 618, which shows a plan of the motor, the change-speed gear, and the mechanical feed pumps. Its cylinders lie transversely, and nearly horizontally, the crank chamber being combined with the gear case. The 12-h p. motor has two cylinders of 72 mm. (2·83 in.) bore, and 80 mm. (3·14 in.) piston stroke. The crank-shaft A, carried in four bearings, passes through the casing at its forward end only (at the top of Fig. 618), and there carries a fan, which draws air through the condenser. The crank-shaft has three spur wheels, B, C, D; the first two are of unequal size, and always mesh with wheels E F respectively, these being mounted on a lay shaft inside the casing, and normally running idly, though either can be clutched to the lay shaft by a two-way jaw clutch, G. This clutch is slid along by a fork, H, when operated by a lever on the steering pillar. A third spur wheel, J, is fixed to the lay shaft, and meshes with wheel K on the inner end of a short shaft passing through the back end of the casing; at the outer end of the short shaft is a universal joint, L, forming part of the longitudinal driving shaft (M, Fig. 617), which drives the live rear axle. Jaw clutches G allow of (1) the motor running free, or (2) driving the car through the low gear C and F, or through the high gear B and E. Ball bearings carry the various shafts. The longitudinal shaft has a telescopic joint (besides the universal joints at each end), so that the drive is flexible. The cranks on the crank-shaft are at right angles to one another, and the double-acting cylinders prevent any dead centres. Link-motion reversing gear operates the slide valves. Steam chest cover M, Fig. 618, is held in place by six studs, and is wedge-shaped to render the slide valve more accessible. The mechanical feed pumps N, O, for water and fuel respectively, are bolted to the sides of the main casing; N is driven by a connecting-rod from a crank pin on a small lay shaft, P; whilst O is driven by an eccentric mounted on shaft P; this shaft carries a spur wheel, Q, which is driven from the crank-shaft by spur wheel D, and as Q is much bigger than D the pumps run at a much lower speed than the motor.

Miesse steam cars, made in two sizes, 6 h.-p. and 10 h.-p. and identical in everything save dimensions, have a rectangular main frame built up of wood, stiffened with steel flitch plates and corner plates. There are five channel-steel cross members, two of which carry the boiler beneath the bonnet in front, one is beneath the dash, and the remaining two support the fuel tank and water tank at the rear. The steam motor is carried in the centre of the frame on two cross channels, which are rigid with brackets bolted to the frame. The cylinders are cast in one piece and are bolted to the crank chamber which also encloses the differential gear on the cross countershaft. The transmission is by side chains as in a petrol car, which, indeed, the Miesse car closely resembles outwardly. Feed water pumps are fixed on the right-hand side of the car and are formed in one casting, one being operated by a hand lever, and the other by an eccentric on the countershaft. An air pump, fixed to the left of the motor, is driven by a crank pin on the end ot the crank-shaft. The flash boiler is built up of several layers of steel tubes, and is heated by a special form of burner which consumes ordinary paraffin. The water is forced into one end of the boiler by a hand pump when starting, and by a mechanically driven pump when the car is running; the quantity of water delivered by the power pump depends upon the speed of the motor, but the actual amount which finds its way into the boiler is regulated by hand, any surplus finding its way back to the supply tank. The hand regulator consists of a bye-pass, and it primarily enables the driver to regulate the steam pressure. The steam is taken direct from the boiler to the motor, the latter being controlled by varying the cut-off and reversing gear; in some cases there is a throttle valve, which is closed by depressing a pedal. A safety valve and a hand-operated relief valve are provided on branch pipes between the water feed pump and the boiler, but the steam pipe from the boiler runs direct to the motor, and has no branch

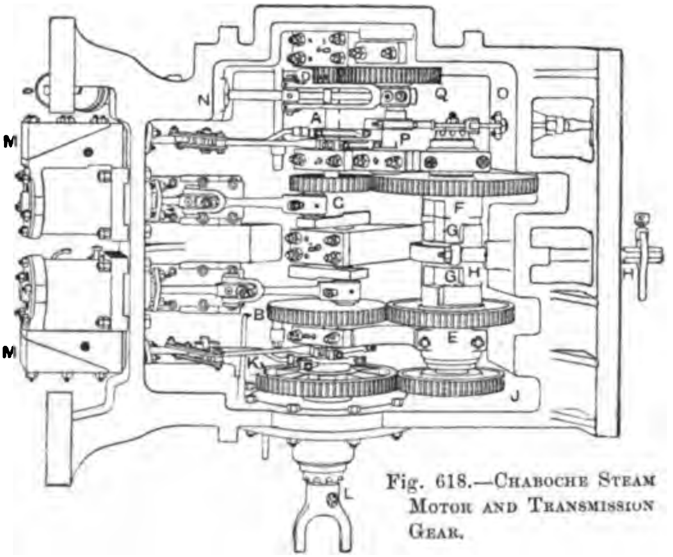


Fig. 618.—Chaboche Steam Motor and Transmission Gear.

connections of any kind. The heat of the burner is regulated entirely by hand, and the fuel is fed from the supply tank to it under pressure. The pressure in the tank is automatically maintained, when running, by a pump driven off the motor crank-shaft, the degree of pressure being kept constant by a relief valve which opens at a certain pressure. The paraffin oil on its way to the burner passes through two vaporising coils which lie above the burner, and the gas generated in the vaporiser is led through the regulating valve to a single nozzle which projects into a pipe forming part of the burner. The quantity of gas is controlled by the driver, but there is no regulator for the air. The air and gas pass along the pipe into a chamber from which a large number of parallel, horizontal tubes project beneath the boiler. To form the burner jets, the tubes are perforated with rows of fine holes, drilled at an angle. The burnt gases are conducted from above the boiler by a flue passing across it and down behind it ; the flue is open to the air in front, and the necessary draught is created by the forward travel of the car. The motor is lubricated entirely on the splash system, oil being fed into the crank chamber for this purpose. The motor consists of three parallel, horizontal, single-acting cylinders, fitted with cam-operated mushroom valves. The crank-shaft has its three crank pins arranged at angles of 120° from one another, and the power is transmitted through a pair of spur wheels to a differential gear enclosed in the same casing with it. The differential gear is mounted upon a countershaft lying across the frame of the car, from the ends of which side chains pass to the rear wheels. The exhaust steam from the motor is led to a radiator in front of the car, and any condensed water, as also any uncondensed steam passing through it, is led back by a pipe to the water tank.

A steam car built two years or so ago by the Automobile Manufacturing Company is shown in side elevation by Fig. 619, and in front and back elevation by Figs. 620 and 621. A flash-type boiler is employed, heated with petroleum, an oscillating type of motor driving direct on the rear axle, an automatic water feed to the boiler, a condenser which enables part of the feed water to be returned to the water tank, and a reheater which renders any uncondensed steam invisible. This car presents considerable deviations from usual practice. Figs. 619, 620, and 621 show that a channel framework carries all the various parts, jointed tie rods connecting the front and rear axles. The boiler B, in front, is heated by a furnace, A, into which the oil and air enter through the passage C. The fuel supply is regulated by a needle valve, adjusted by a system of levers, of which D is one. The steam from the boiler B passes to a distributing valve, F, which directs it into either the two cut-off valves G or into the trunnion valves H. The distributing valve F also changes over the connections of the main exhaust pipe to the other of these supply and exhaust valves, at the same time that it changes over the live steam connections to them. In this particular car the valve F, which may be called a reversing valve, is circular, the live steam being on the upper and the expanded steam on the lower side. By rotating the valve the motor is reversed and the degree of throttle varied. This valve is actuated by hand through the rods J and K. When running forwards, the steam passes through the cut-off valves G to the outside trunnion valves H of two oscillating cylinders L. The sliding blocks M, actuated by the hand lever N through the rod O, enable the cut-off of both of the cylinders to be varied as desired. Two double-acting cylinders L are carried by trunnions upon arms, mounted at their other ends about the rear axle. The cylinders have a bore of 10·16 cm. (4 in.) and a stroke of 22·3 cm. (8·8 in.); and their piston-rod ends are connected to cranks forming part of the rear axle. The two cranks are set at 90° from each

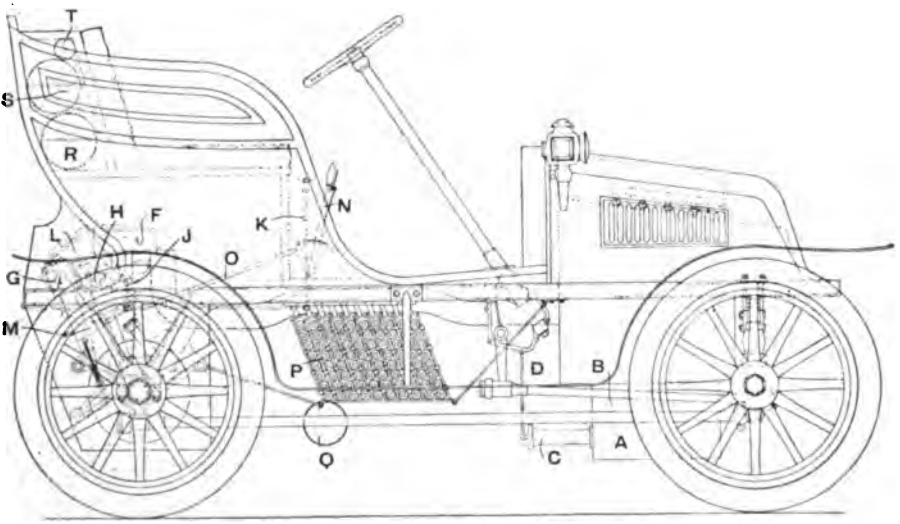


Fig. 619.—Side Elevation of Automobile Manufacturing Company's Steam Car.

other, and thus avoid any dead points. The cylinders L oscillate upon trunnions, and so control the admission and exhaust of steam to and from themselves. The exhaust steam passes from the distributing valve F to a large condenser, P, underneath the frame, whose other end leads into the chamber Q, where any condensed steam collects. A pipe (not shown) leads from the bottom of the chamber Q into a water tank under the seat. This pipe forms a coil in the water tank, and terminates above the surface of the water. From the top of this tank a pipe leads into the flue of the boiler. Thus steam is condensed, and the water formed is driven up into the water tank. If, however, the condenser is unable to condense all the steam, the surplus passes through the coil in the water tank and, if still uncondensed, passes into the hot flue of the boiler and is reheated before going into the atmosphere. The paraffin tanks R and S, and an air tank, T, also are fitted at the back of the seat, a petrol tank being placed under the seat.

Fig. 620.

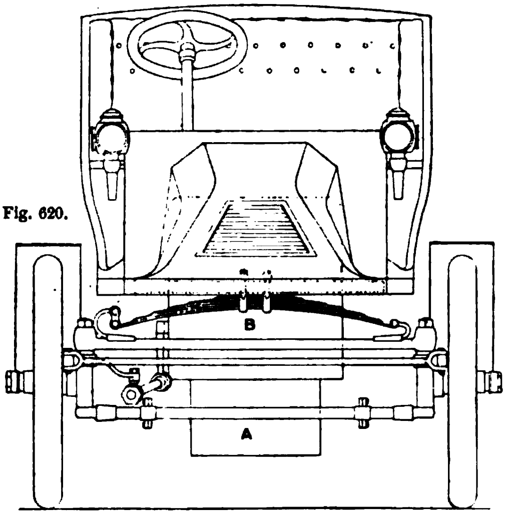
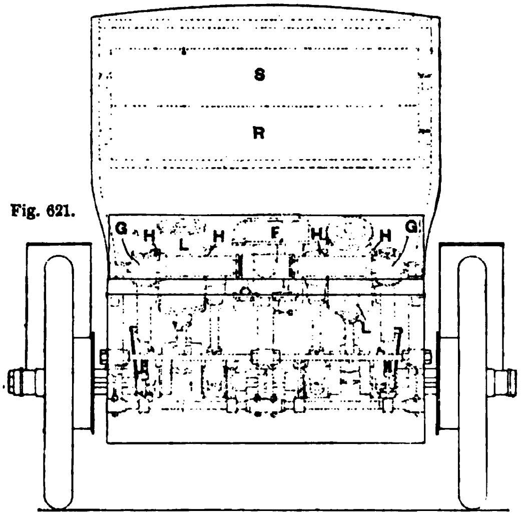


Fig. 621.



Figs. 620 and 621.—Front and Back Elevation of Automobile Manufacturing Company's Steam Car.

The fuel and water connections of the above car are shown by Fig. 622. A two-way cock, A, enables either petroleum or petrol spirit to pass to a second two-way cock, B, which either passes the fuel by the pipe C to a starting coil, D, and thence by the pipe E to the spray nozzle F, or it allows the oil to flow through the pipe G and the heating coil H to pipe E. The coil D, before starting, is heated by a spirit flame, S. A motor driven pump draws water from the supply tank through the pipe J, and forces it by the pipe K into a cylinder, L, of the regulator. A plan of the regulator M is given below the elevational view. A piston, N, fits in the cylinder L, and normally is held in its inner position by springs O.

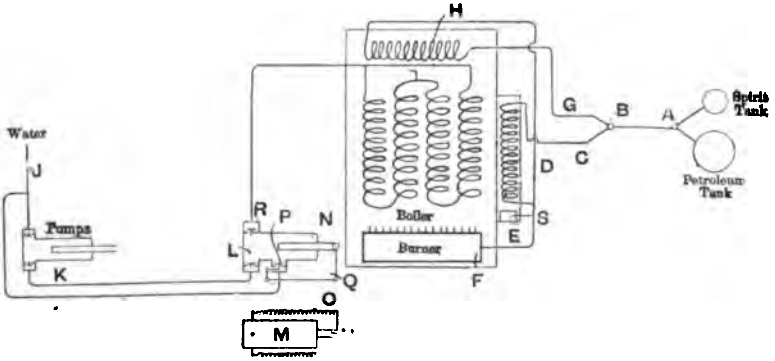


Fig. 622.—Connections on Automobile Manufacturing Company's Steam Car.

The water entering the cylinder L tends to force the piston N outwards, and when the water pressure is sufficient to overcome the springs O the piston travels outwards, and in so doing opens a byepass valve, P, through a system of levers, Q, and allows water to return to the suction pipe J. The water flows from the cylinder L into the boiler by the pipe R whenever the pressure in the boiler becomes less than that due to the springs O.

Among American steam cars the White car (Fig. 623) has unique features. It has a "semi-flash" boiler (p. 72), to which the fuel feed is regulated automatically by the steam temperature, and the water feed by the steam pressure; the car can run quite automatically. At first the fuel feed is regulated by hand from the driver's seat, it being reduced automatically only when the steam temperature exceeds about 800 degrees F. A thermostat insures a supply of dry superheated steam, and regulates the fuel feed to meet the more important requirements. The thermostat, lying across the burner, is enclosed in a pipe, through which the steam passes on its way from the bottom coil of the boiler up to the throttle valve; the burner further superheats the steam and causes the thermostat to open or close the petrol valve.

The White thermostat is a steel rod enclosed in a brass tube, both being fixed together at the end; the tube expanding more than the rod gives the latter a longitudinal movement. It never quite cuts off the fuel supply, a certain amount of petrol spirit always passing through the valve. Steam pressure is controlled by a hand regulator. The feed water supply force pump is driven by the double-acting two-cylinder motor (p. 86); the amount entering the boiler depends on the steam pressure in the boiler itself, a bye-pass leading back to the suction side of the pump being controlled by it through a diaphragm valve; at a certain pressure the bye-pass opens fully and returns the whole of the feed water to the supply tank. Below a certain pressure all the water is delivered, and at intermediate pressures the quantity is in proportion. But when the bye-pass is fully open, there is still a good quantity of water in the boiler's upper coils, and steam is still generated. In addition, there is a hand pump for injecting water into the coils at any time. The burner (p. 74) is another interesting feature. All exhaust steam from the motor is condensed in a large front radiator and pumped back to the main tank; this is one of the chief advantages of using a flash boiler. A cotton-waste chamber removes the bulk of the oil from the condensed water, and any small quantity remaining is of no importance. This allows of a very low water consumption, less than 17 l. per 100 km. (6 gal. per 100 miles).

To describe the White fuel and water connections in detail, A, Fig. 624, p. 572, shows the petrol spirit tank connected with hand-pump B, and a motor-driven air-pump through the shut-off valve C; B and C are within easy reach of the driver. The burner feed pipe D, containing shut-off cock E, branches into F and G, the former feeding the pilot lamp H, and the latter the vaporising tube J through the thermostat regulator K; these parts are illustrated in detail on p. 73.

In the White system of water connections shown by Fig. 625, p. 753, A is the tank connected to the supply pipe B by a fitting enclosing a removable strainer, C; B leads to a hand pump, D, and to the motor-driven force pump E. When the stop valve F on the hand pump delivery pipe is open, water can be pumped direct into the boiler through connection G, irrespective of the automatic diaphragm valve regulator H; the stop valve F prevents leakage. The force pump delivery pipe J leads to a T-fitting K, through which the water passes normally to connection G; between K and G is a check valve to prevent the automatic regulator H affecting the hand feed. The T-fitting K screws on to H. Pipe L is in connection with the live steam between the boiler and the throttle, and according to its pressure on a diaphragm within H, so more or less water is allowed to pass through K, H, and bye-pass M back to N, which is at the

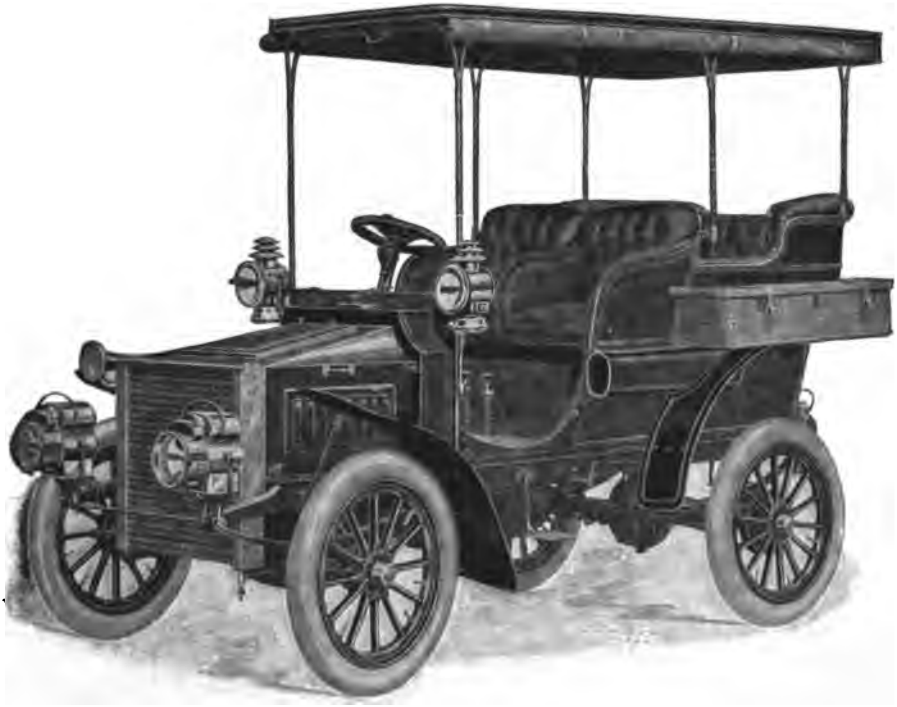


Fig. 623.—White Steam Car.

suction side of the two pumps, D E. The pressure at which H comes into action is adjustable. O is a blow-off cock.

The axles of the White car, tied together by hickory reaches, are tubular, the front one being bowed upwardly to its centre, the stay carrying the live rear axle being shaped similarly (the drive is by a single chain from a sprocket on the crankshaft to one on the live axle differential). The suspension springs are secured to brackets fixed to the bowed tubes; the rear springs have top and bottom rubber blocks to limit compression on rough roads, and the tube carrying the rear axle terminates in a fork at each end, in which the axle is pivoted, and is thus self-aligning. Two forked, adjustable distance rods pass from the axle to the motor. For steering, a tiller is used.

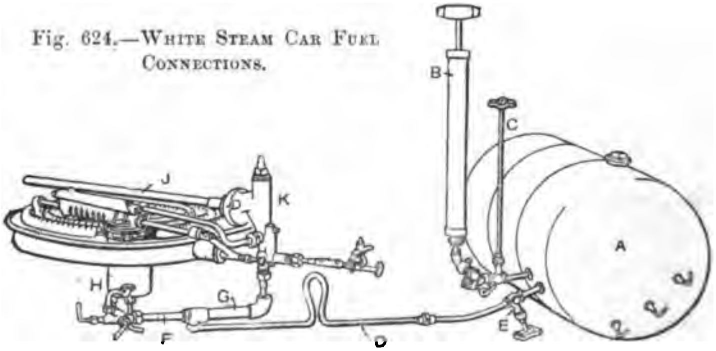


Fig. 624.—White Steam Car Fuel Connections.

The four equal road wheels are 76·2 cm. (30 in.) in diameter, and have either Goodrich or Clipper tyres. The wheel base is 183 cm. (6 ft.). The boiler and burner are immediately behind the seat, the motor is under the seat, the water tank surrounds the rear of the boiler, and the petrol tank is below the footboard. Under the seat and to the right of the motor is the lubricating oil tank, and the condenser, not unlike a petrol car radiator, is carried in front, as illustrated in Fig. 623.

A new White car, nominally 10 h.p., cannot outwardly be distinguished from a petrol car. It seats four passengers, has wheel steering, the two-cylinder vertical compound motor with longitudinal crankshaft is underneath a front bonnet, which has a radiator-like condenser, and the drive is through a universally jointed propeller shaft to a live rear axle. The body is of the high-backed tonneau type. The wheel base is 203·2 cm. (6 ft. 8 in.), the tread 142·2 cm. (4 ft. 8 in.), and the wheels are the same as before. A 68 l. (15 gal.) water tank and a 45·4 l. (10 gal.) petrol spirit tank are carried, and the car in running order weighs about three quarters of a ton.

The Lamplough-Albany is a new English steam car that outwardly greatly resembles a petrol car; the honeycomb condenser in front of the long, square-ended bonnet, underneath which is a semi-flash boiler, aids the resemblance. The motor has four single-acting horizontal cylinders arranged in opposite pairs, and is fixed behind the boiler; a central gear wheel on its longitudinal crank-shaft transmits power to an underneath shaft which drives the live rear axle through a universally jointed shaft and bevel gearing. At a boiler pressure between 21 kg. and 28 kg. per cm.^{2} (300 lb. and 400 lb. per sq. in.) the motor develops 24 h.p. The burner uses either petrol spirit or paraffin. Automatic pumps and hand pumps are fitted for fuel and water feeds, and the exhaust steam is condensed and used again. Speed is regulated entirely by varying the cut-off of the steam.

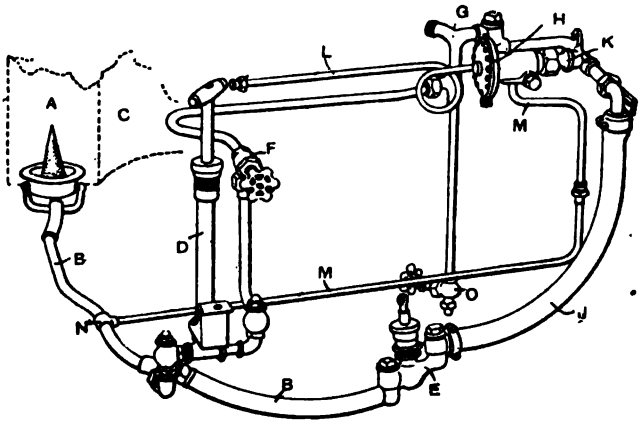


Fig. 625.—White Steam Car Water Connections.

As regards driving fore-carriages, in studying the petrol and electric vehicles in following chapters, some driving fore-carriages will be described and their advantages pointed out, but it is not thought that hitherto any steam fore-carriages have been built; this is not to be wondered at, because it seems somewhat difficult to lodge a boiler, motor, and the transmission and steering gear, all on a single axle.

Nevertheless, a fore-carriage has been attempted by Turgan and Foy, in whose arrangement the fore-carriage supports a Turgan boiler; the horizontal driving shaft has a bevel pinion which gears directly with a second pinion keyed on a vertical shaft passing through the axis of a pivot formed of a tube. At the lower part of this shaft another bevel wheel directly gears with the differential box of the axle upon which the wheels are keyed, and to compensate for the variations of distance which, on account of the suspension springs, separate the frame from the axle, there are two parts united by a nipper spring, which is here preferred to the universal joint.

CHAPTER XVIII.

PETROL AUTOMOBILE CARRIAGES.

THE plan or general arrangement of a petrol carriage first must be understood. A petrol carriage should comprise the petrol spirit tank, the carburetter, the igniting device with battery or other electric generator, or, if incandescent tubes, with burners fed by a small petrol spirit tank in which a suitable pressure is maintained by aid of a hand pump, the motor with its distributing and governing appliances and sometimes an accelerator to neutralise the governor when desired, the cooler, usually a radiator, pump and water tank, the exhaust silencer, the transmission gear, usually comprising (*a*) the main clutch, (*b*) the speed-change gear, (*c*) a differential countershaft and endless chains driving the rear wheels (or, instead, a universally jointed longitudinal shaft driving a live rear axle through bevel gearing), and a reversing device, two brakes automatically cutting off communication of motor and transmission gear, one acting on the differential countershaft and the other on the driving wheels, sprag or a pawl to prevent recoil, two axles, one driving and the other steering, the main frame, sometimes an underframe, the body, and lubricating apparatus. There is not in all this complication the simplicity of the steam car, still less that of the electric car; but all petrol vehicles have not the multiplicity of parts just enumerated. Voiturettes often have no reversing gear, and tricycles and quadricycles are much more simple than are regular cars.

Voiturettes comprise vehicles with three or four wheels, in construction resemble a car, and have a regular passenger seat. The voiturette may not have suspension, water cooling, or reversing gear, though Act 5 of the French Regulations compels automobiles weighing empty more than 250 kg. (550 lb.) to have a reversing gear. Many modern voiturettes are ordinary cars in miniature.

Tricycles and quadricycles comprise vehicles with three and four wheels similar in construction to cycles, there being neither suspension nor reversing gear, and the rider's seat being a saddle. These vehicles are known as "motor cycles," which also may comprise some voiturettes. The definition of motor cycles given by the French regulations:—Any vehicle with mechanical traction weighing less than 150 kg. (330 lb.) empty, that is, without passengers, fuel, water, and spare parts, is a motor cycle.

The Singer motor tricycle (Fig. 626) employs the motor wheels illustrated in detail by Fig. 803, p. 761, and there described. The extreme width of the main axle is 89 cm. (35 in.), and the total weight, as stated by the makers, is only about 63·5 kg. (140 lb.), certainly a low weight.

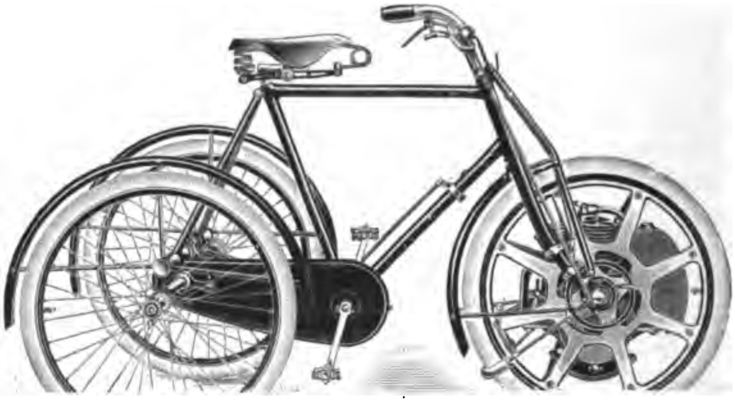


Fig. 626.—Singer Petrol Motor Tricycle.

The Ariel motor tricycle is illustrated by Fig. 627, and its construction may be understood with ease. A is the carburetter; B, battery; C, cylinder of 2¾ h.p. motor; D, crank chamber; E, glass reservoir of lubricating oil; H, compression tap; I, lever to open compression tap; J, lever for timing spark; K, tube connection between carburetter and motor; L, induction coil for battery; M, tell-tale wire showing quantity of petrol spirit in carburetter; N, lever for controlling supply of carburetted mixture; O, lever for regulating supply of air; P, band brake; Q, screw, at whose end is a needle valve for regulating supply of petrol spirit from spare tank to carburetter; R, sparking plug to explode mixture; S, encased gear wheel propelled by small driving wheel on left side of crank chamber; T, screw plug for filling carburetter; U, inlet to lubricating oil reservoir; V, inlet valve through which vapour passes from carburetter to motor cylinder; W, motor combustion chamber; X, handlebar switch; Y, loose plug switch; and Z, tube in which a portion of the hot exhaust gases passes through the carburetter to warm the spirit. The vertical section of motor and carburetter shown by Fig. 628 will serve to make the construction even clearer. In this figure, A is the carburetter; B, the battery; C, spare tank; D, needle valve for feeding carburetter; E, tell-tale wire; F, mixing chamber; G, tube from carburetter to motor; H, mixture inlet valve; I, combustion chamber; J, cylinder; K, piston; L, connecting rod; M, crank; N, fly-wheel; O, exhaust valve, with cam, P; Q, contact breaker; R, ignition plug; S, tube for warming petrol spirit; T, silencer; U, induction coil; V, handlebar switch; W, driving pinion; and X, compression tap.

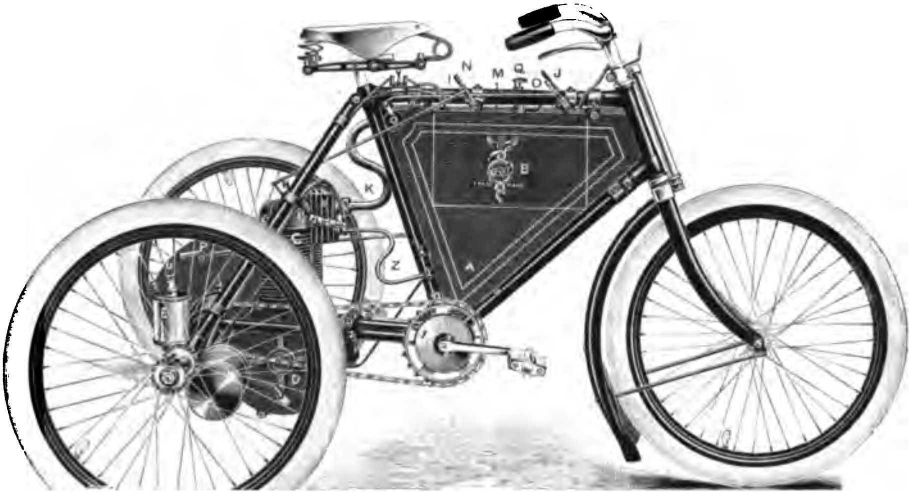


Fig. 627.—Ariel Petrol Motor Tricycle.

The petrol cars described in this chapter are classified broadly as (1) those with vertical and inclined motors and (2) those with horizontal motors. This classification is adopted because often the employment of a horizontal motor necessitates a radical alteration in the type and arrangement of the transmission gear and produces cars of a distinctive design. Both of these classes are subdivided into: (*a*) cars with side chain transmissions and fixed axles, (*b*) those with live rear axles driven by longitudinal shafts through bevel gearing, and (c) those with live rear axles driven by chains or in some other way. In subdivision (*a*) of the first class, a few leading types of car are described first and in detail, succeeding descriptions of other constructions being more general or confining themselves to special and characteristic features.

English Daimler cars now being placed on the market are of 12 h.p. and 22 h.p. There is but little difference between them. The 12-h.p. car is shown in side elevation, with the gear box in section, in Fig. 629, and in plan in Fig. 630. The rectangular main frame A is of wood strengthened with steel flitch plates; a pair of plates lie alongside the inner face of the two longitudinal members and taper from their centres downwards, both forward and rearward. A pair of cross angle pieces, B, are arranged in front, and another transverse member, C, serves to support the rear end of the change-speed gear. The underframe D, suspended from the members B, carries the four-cylinder motor. The motor is described on pp. 209 to 211 and the carburetter on p. 119. In Figs. 629 and 630, E represents the cylinders; F the crank chamber; and G the combined fly-wheel and clutch shell. The main clutch, operated by pedal H,

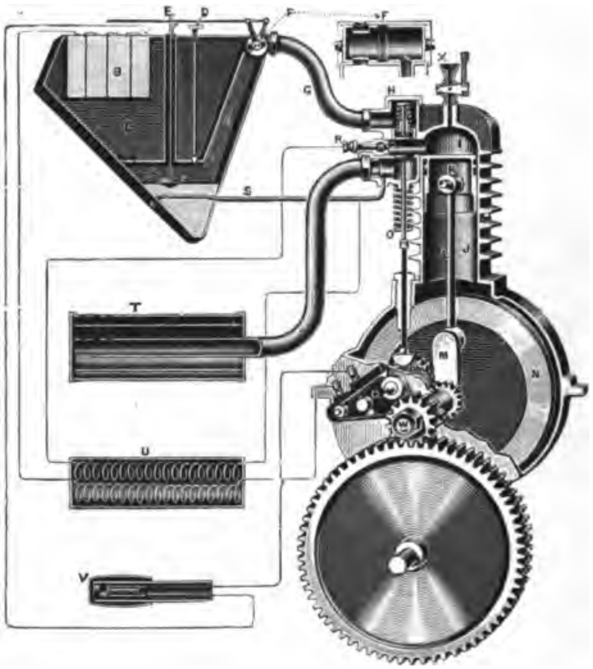


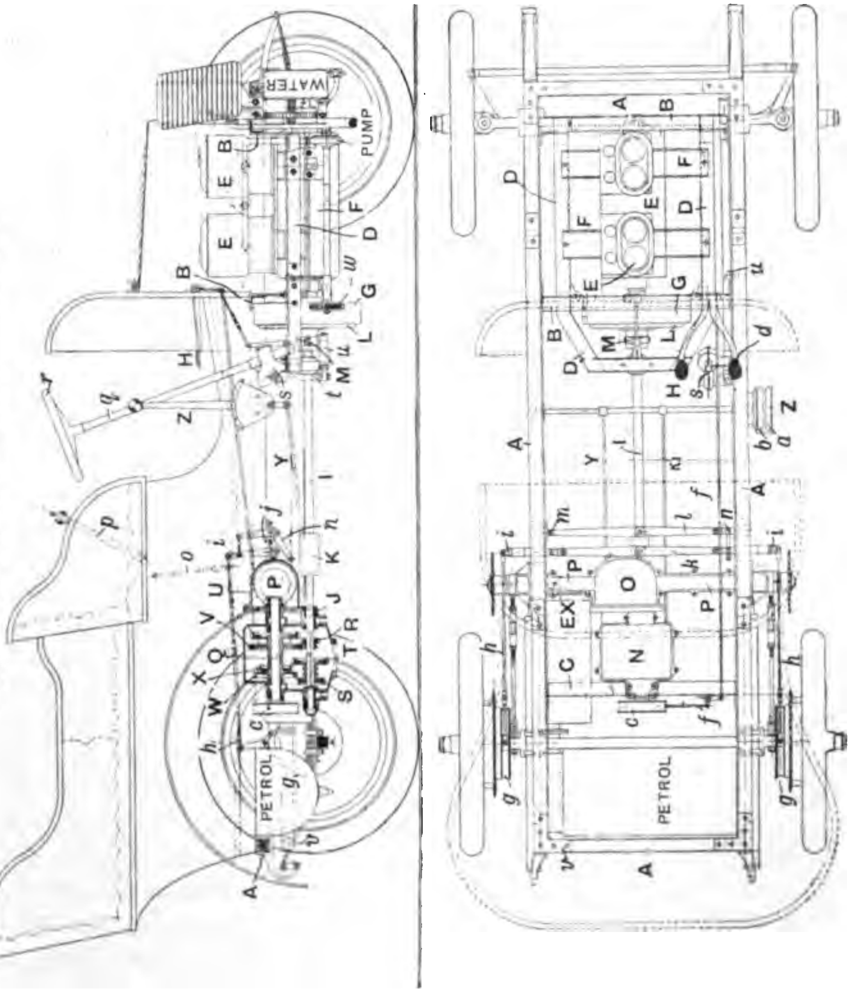
Fig. 628.—Section of Ariel Petrol Motor.

connects the motor shaft with the longitudinal shaft I, leading to the first motion shaft J of the change-speed gear. Between I and J is a flexible coupling, K, which allows I to slide longitudinally, together with the male portion, L, of the clutch; L is of aluminium, with a friction surface of leather, a steel spring fitted between leather and metal causing a more gradual engagement. The steel is formed into a ring which encircles the aluminium, and has projecting tongues each acting as independent springs. The large stationary spiral spring, normally holding the clutch in engagement, acts upon fork M, which imparts a sliding motion to longitudinal shaft I, a ball-bearing taking the thrust between fork and shaft. This spring, not shown in the drawings, lies immediately above the longitudinal shaft, and passes rearward from the clutch fork; it is so arranged that when the hand brake is operated the normally fixed end of the spring is forced forward by a cam, and the clutch is thus released. Application of the foot brake withdraws the clutch in the same manner as depressing the clutch pedal, namely, by a direct action upon the fork M, overcoming the pull of the spring. The spring is unusually accessible, and its strength is adjustable. The change-speed gear is enclosed in the casing N, rigid with transverse casing O, which contains the differential gear and countershaft. The aluminium casing is fixed to each side of the main frame, and to the cross member C. The complete gear box can be removed, downwards, when necessary. The eight ring lubricator bearings have oil-retaining bases, connected by pipes with three feeders; these feeders each have gauge glasses to show the level of the oil in the bearing bases.

The English Daimler transmission is by 38 mm. (1·5 in.) pitch roller chains from side sprockets on the counter-shaft P to each of the rear wheels. The first motion shaft J lies immediately beneath the second motion shaft Q, which carries a bevel wheel at its forward end, meshing with a corresponding and larger wheel fixed to the differential gear drum. The first motion shaft is of square section inside the gear box, and carries sliding spur wheels, R, S, and T, which respectively provide for the low, intermediate, and top speeds. Wheel R is mounted independently, and S and T are carried by a common sleeve. Each of these sliding parts is moved longitudinally by a separate rod, there being one rod on each side of the gear box. The second motion shaft Q carries four spur wheels, U, V, W, and X. At all times U is in mesh with an intermediate pinion, which also gears with the sliding wheel R, when in its front (or reverse) position. The other three wheels correspond with R, S, T. The two sliding rods which bring either train of wheels into play are connected respectively to a rocking shaft and a concentric sleeve by the rods Y. The hand lever Z engages with one or other of them, according as to whether it is moved sideways into the slotted quadrant *a*, or into the slot *b*. The lever in its central position can be moved into either slot, its "off" position being between them. When moved away from the driver, it slides the one sleeve rearwards, or when moved towards him it slides it forward. In the one slot it alternately brings the reverse or the low speed into play, and in the other slot it brings either the second or the third speed into operation. The differential gear has two bevel planet wheels, and is kept well lubricated by a feed pipe which leads the oil into the centre of it; the oil is unable to find its way back through this pipe for the same reason that the ink in a well-known shape of ink-pot is not spilt even when the pot is upset. Two distance rods pass from the rear axle, and serve to tighten the side chains; they are held at their forward ends by sockets fitting over the brackets which support the aluminium gear case. They cannot put any strain on the countershaft bearings, although they swing about the same centre.

A double-acting band brake works on the water-jacket drum *c*, mounted on the rear end of the second motion shaft Q, outside the gear case; and it is operated by pedal *d* through connecting rods *f*. The side brakes *g* are also double-acting; the drums are fixed to the rear wheels, and the operating rods *h* are carried by the ends of levers *i* pivoted at *j*. The levers *i* are connected to the ends of a horizontal lever, *k*, a swinging coupling at the centre of which connects it with a practically parallel lever, *l*; this lever is pivoted at *m* on the near side of the frame, and the opposite end is operated by a bell crank lever, *n*, which in turn is connected through an adjustable rod, *o*, with a hand lever, *p*, fitted beside the driver's seat inside the body of the car. By this arrangement, the pull on the two side brakes is equalised when the brakes are applied, for the lever *k* is free to assume whatever angle it pleases in a horizontal plane so far as the action of the hand lever *p* upon it is concerned. Its two ends being connected to the two brakes, it will lie at such an angle that the tension on the two connecting rods *g* is the same.

The inclined steering pillar *q* carries hand wheel *r*. The worm gear is in case, *s*, and a projecting arm, *t*, is connected to the front wheel by rod *u* in much the usual manner; adjustable ball sockets are fitted to the various knuckle joints.



Figs. 629 and 630.—English-Daimler 12-h.p. Car.

The petrol tank at the rear is at such a height above the carburetter that the motor can be started with a gravity feed. When working, the exhaust gases maintain a pressure within this tank, as also within the lubricating oil tank. The petrol tank is divided into two parts, one holding 36 l. (8 gal.), and the other half that, and by means of a two-way cock the petrol can be led from either tank alternately. From the exhaust box E X, between countershaft and rear axle, the gases pass into a cross pipe, *v*, perforated on its under side. The water tank is in front, and the starting handle passes through a tube forming part of it. The ribbed aluminium radiator is immediately above it, and its sides are connected together by horizontal flanged tubes passing across the car. The circulating pump, of the centrifugal type, is chain-driven from the motor crankshaft; the driving sprocket is fixed between the crank chamber and the fly-wheel, and the driven one, *w*, is on the pump shaft, as the radiator is arranged at a higher level than the cylinders, and the pump is of the centrifugal type, natural circulation of the water would occur even if the pump were out of order. The motor and other parts beneath the bonnet are shielded from the dust by a sheet metal casing underneath them. The dash with curved sides is fitted with cupboards, and carries the commutator, motor lubricators, and a three-way cock. The commutator is chain-driven from the motor. The three-way cock allows water to be fed into the brake drum and relieves the pressure on the fuel and lubrication tanks when desired. All four road wheels are of the artillery type, and have a diameter of 81·3 cm. (32 in.) over the pneumatic tyres. The wheel base is 2·03 m. (7 ft. 6 in.); the gauge is 124·5 cm. (4 ft. 1 in.); the weight without body is 711 kg. to 762 kg. (14 to 15 cwt.), and the car is geared from 38·6 km. to 58 km. (24 to 36 miles per hour).

The English Daimler 22-h.p. car is shown in Fig. 631. In general respects it resembles the 12-h.p. vehicle, but it is much larger, and owing to there being four forward speeds provided by the gear wheels R, S, T, and T^1, which alternately mesh with the corresponding wheels V, W, X, and X^1, a separate lever is used for bringing an intermediate spur wheel into play for giving the reverse. The additional reversing lever is a small inconvenience probably more than made up for by the fact that this wide intermediate reversing wheel only revolves when actually in use. One of the few differences in design is that the fork M, which operates the main clutch, is arranged outside the underframe instead of being within it. F L is the petrol tank filler and S T the starting handle; other letters and constructional details will be understood from Figs. 629 and 630. The four wheels are 91·4 cm. (36 in.) in diameter: the wheel base is 2·28 m.

(7 ft. 6 in.); the gauge is 141 cm. (4 ft. 7·5 in.); the weight of the chassis is about 1,120 kg. (22 cwt.), and the cars are geared to 64 km. or 80 km. (40 or 50 miles) per hour on the top gear with the motor running at normal speed.

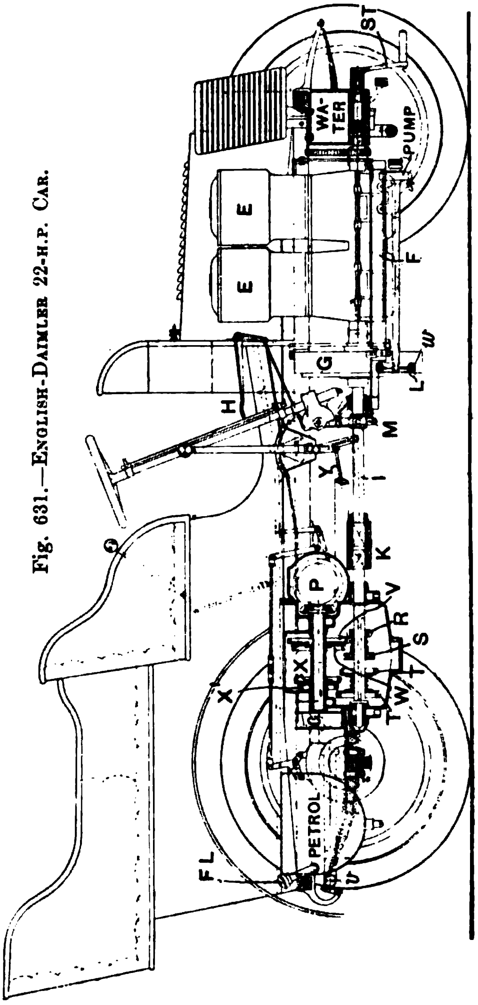


Fig. 631.—English-Daimler 22-h.p. Car.

Mercedes cars are the justly renowned vehicles manufactured by the Daimler Motoren Gesellschaft, Cannstatt, Germany, to the designs of Mr. Mercedes. The 1902 cars, as exhibited at Paris in December, 1902, were of 28 and 40-h.p. respectively, but the 1903 cars apparently are standardised in the two sizes, 18-25 h.p. and 60-h.p., and these, except for detail differences and dimensions, are alike. A general view of the chassis of the 18-25 h.p. car is given by the reproduced photograph, Fig. 632. The motor is four-cylinder and of advanced design, full particulars of it being given on p. 212. The carburetter has a butterfly throttle valve. The honeycomb combined radiator and tank (p. 198) is a speciality of Mercedes cars; in this car the radiator has 5,000 tubes, the space between them being only ·25 mm. (·009 in.), and the capacity being 11 l. (2·42 gal.). The frame is of stamped steel, differing considerably from previous constructions. The main clutch is of the new expanding type, its construction being illustrated and described on p. 373. The change-speed gear is a new design of the spur-wheel type, and is described in detail on p. 389; it may, however, be mentioned that the gear box employs ball bearings throughout, and that quite recently the design has been again changed, and a cam plate is not now used to bring the different gears into engagement, except on a 90-h.p. racing machine. The countershaft sprocket wheels which chain-drive the rear road wheels, have no spokes between hub and rim, there being a continuous web instead.

The change-speed lever in previous Mercedes models was moved forward or backward to one of two alternative positions only in alternative slots, being free to move sideways when in a vertical position; this system was replaced by the more popular one in which the lever is moved progressively forward and backward over a single quadrant for all the four forward speeds and reverse. But this again has been abandoned and a modification of the earlier system has been adopted. The quadrant now has four slots, and is so shaped that the lever cannot be moved into the reverse slot until a catch engaging with the quadrant has been raised by depressing a push rod; this catch, however, is not raised for changing from one forward speed to another, and so long as it remains in its normal position, the reverse cannot be brought into use. The countershaft brake is water-cooled, and one of the levers connecting it with the operating pedal automatically opens a valve through which the water passes into the brake drum when the pedal is depressed, a cock on the dash controlling the water feed to the valve and drum. The rear wheel brakes of the internal type are exceptionally powerful, and are applied by means of wire ropes. Radius rods connecting the frame with the back axle are of I section, and are very strong. The axles are of T section, not round as in previous cars. The tyres are Continental Clipper, the front ones being 910 mm. by 90 mm. (35·8 in. by 3·5 in.), and the back one 920 mm. by 120 mm. (36·2 in. by 4·74 in.). The wheel base is 233 cm. (91·7 in.). The smaller car has been stated to weigh with a touring body from 750 to 800 kg. (1,650 lb. to 1,760 lb.) the chassis alone weighing 610 kg. (1,345 lb.), the top speed being about 70 km. (43·5 miles) per hour; but a car of this type used by Mr. Mercedes at Nice, early in 1903, weighed without water and petrol 1,040 kg. (nearly 2,300 lb.).

The elements of the Panhard and Levassor car have already been described and illustrated in detail, and nothing remains but to sum up its features, and to give a general idea as to the design and construction of the car. It is in many features typical of modern practice, owing to its having served as a model for English and Continental makers. The higher-powered cars (Fig. 633) conform to the following description. A straight wooden frame, reinforced with steel, carries the Centaure four-cylinder motor (p. 213) in front; this has generally both tube and electric ignition, and a dynamo, driven from the motor flywheel, may supply the current. The Krebs new carburetter employed is described on pp. 141 to 144. The water circulation is effected by a rotary pump, and cooling is by means of a gilled radiator. A clutch (p. 370) connects the motor with the change-speed gear (p. 386), which gives four forward speeds and a reverse, all operated by one lever, and the transmission is by the well-known Panhard side chain system. Steering is irreversible (p. 442), and there is a double-acting countershaft brake and two side ones. The lubricator is of the Dubrulle make. Panhard cars are made in all the known types, but the four standard designs for ordinary use at present are 7-h.p., 10-h.p., 15-h.p. tourist car, and 15-h.p. light car. The first has, as its distinguishing features, a two-cylinder motor with tube ignition, and a gear giving three forward speeds and a reverse. The three others conform to the description given above.

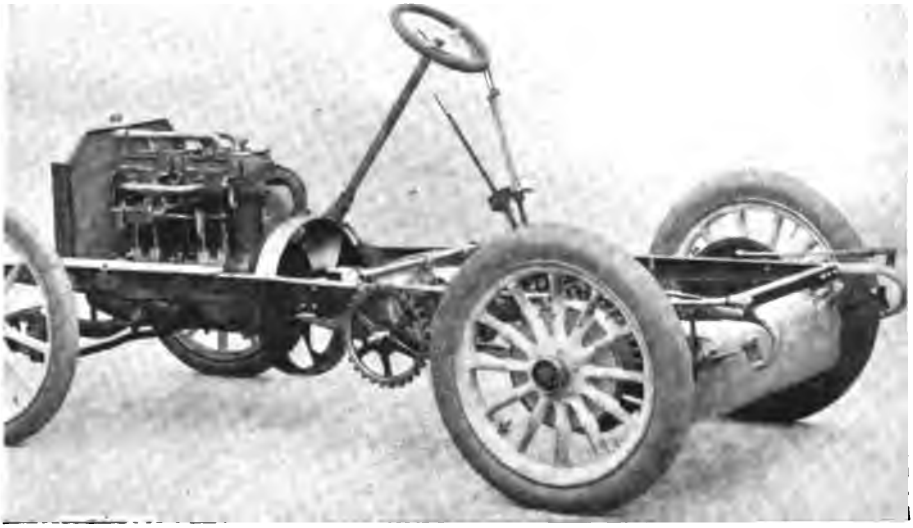


Fig. 632.—Chassis of Mercedes Car.

The Napier is probably at present the best known all-British car, and much of its popularity dates from the Gordon-Bennett race of 1902, which was won in very good time by a car of this make, driven by Mr. S. F. Edge (*see* p. 788). There are five principal sizes: a nominal 9-h.p. two-cylinder, giving actually 12-h.p., 12 and 16-h.p. four-cylinder, giving respectively 15 and 2 -h.p., and a 20 and 40-h.p. four-cylinder, braking up to 38 and 65-h.p. respectively. The nominal 12-h.p. (15 brake-h.p.) is selected as the type for description here, this being identical except in power to the 16-h.p. (24 brake-h.p.) car, shown by Fig. 634. A side elevation of the chassis is illustrated by Fig. 635, whilst Fig. 636 is a view of the chassis taken from above and in front. The letters refer to Figs. 635 and 636. The four-cylinder motor has two pairs of cylinders, each pair being in one piece with its heads and jackets. Its four-throw crank is machined from a solid forging. The crank chamber is in two pieces, divided horizontally through the main bearings, and the cam shaft is

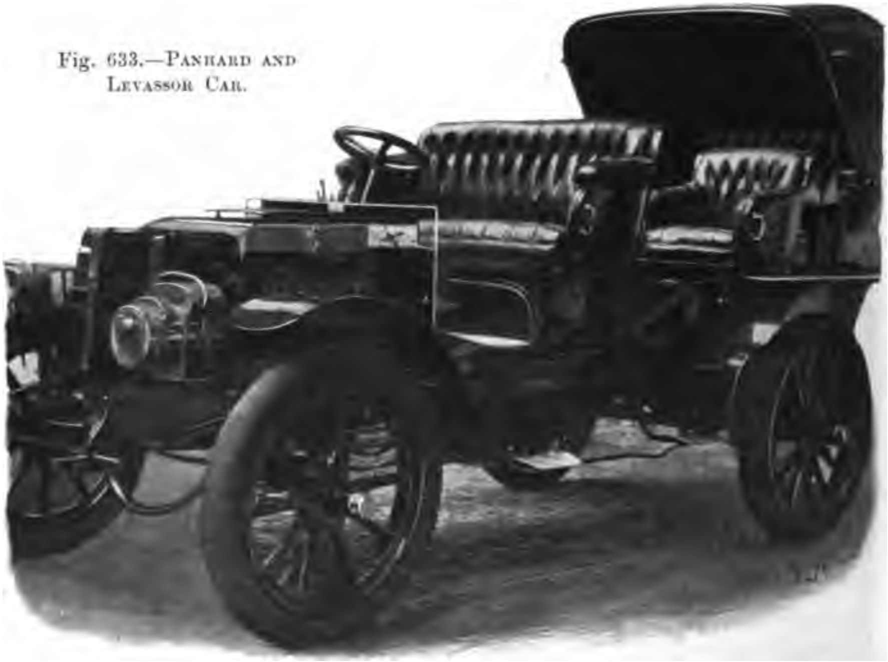


Fig. 633.—Panhard and Levassor Car.

carried inside the upper portion. The spur wheels driving the cam shaft are encased at the front end of the crank chamber, and all these parts run in an oil bath. The supply pipe A from the spray carburetter B branches to each pair of cylinders; the casting C, which serves the double purpose of holding the inlet valves in place on each pair of cylinders and of conducting the explosive mixture to them, can be removed by taking off one nut and by slackening two others; the last-named holds the flange coupling, which joins the induction pipe A to the casting C. Thus the valves are removable easily, and the forked supply pipe A need not be removed to inspect them. The centrifugal force governor is mounted on a separate shaft, and is driven by a chain; the same chain drives the fan behind the Albany radiator D, and is itself driven from a sprocket on the front end of the cam shaft, the chain taking a triangular course and running over three sprockets.

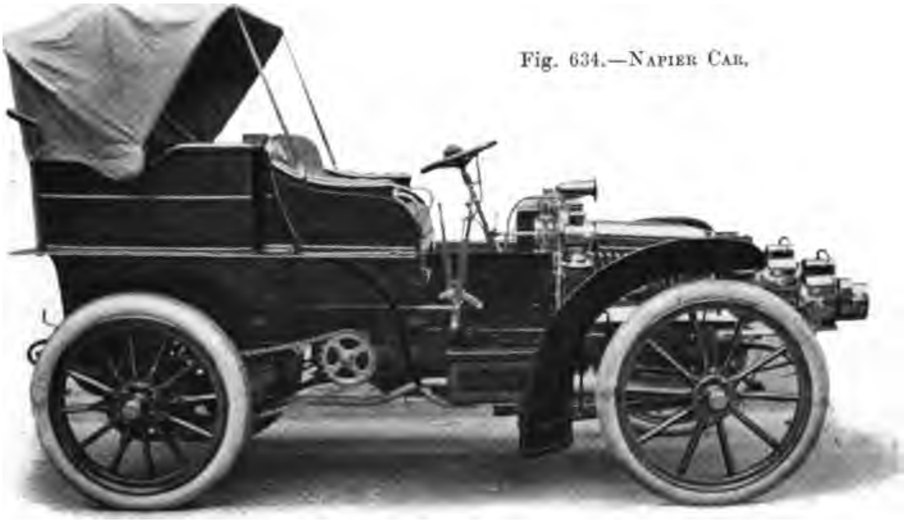


Fig. 634.—Napier Car.

The governor has weak springs, and acts upon a piston throttle valve forming a part of the carburetter; normally, the governor causes a very low speed, but by means of an accelerator pedal the throttle valve can be opened as desired independently of the governor. (In a particular car, there were for each pair of cylinders additional throttle valves in the castings C, interconnected by a rod hand, operated from the dash-board). Separate exhaust pipes, E, are taken from each cylinder to a first exhaust box, X, at the side of the motor, and thence the gases pass through pipe Y to the exhaust box proper, Z, lying beneath the frame at the rear, this system being most effectual in silencing the noise. For supplying the carburetter B with warm air, the two inner exhaust pipes E have enveloping pipes or sockets, F, of much larger diameter, and the air contained in the space between the outer surface of the exhaust pipes and the inner surface of the enveloping pipes becomes warmed, and is conducted through a horizontal T-tube, G, to the other side of the motor to the carburetter B. Current for the ignition plugs H is supplied by accumulator and quadruple coil, the commutator on the dash being driven by the motor through chain J. K shows the timing rod, and L the toothed quadrant on it, whilst M is the quadrant on the commutator. A Dubrulle lubricator, N, on the dash is driven by the chain O. The flywheel drives a rotary water pump, the water tank holding a supply for about 320 km. (200 miles). With regard to the water connections, P is the pipe connecting the two jackets, Q the connection from top of rear jacket to the radiator, and R the pipe from the radiator, whose form is clearly illustrated, to the bottom of the front jacket. The description of the motor is now sufficiently complete.

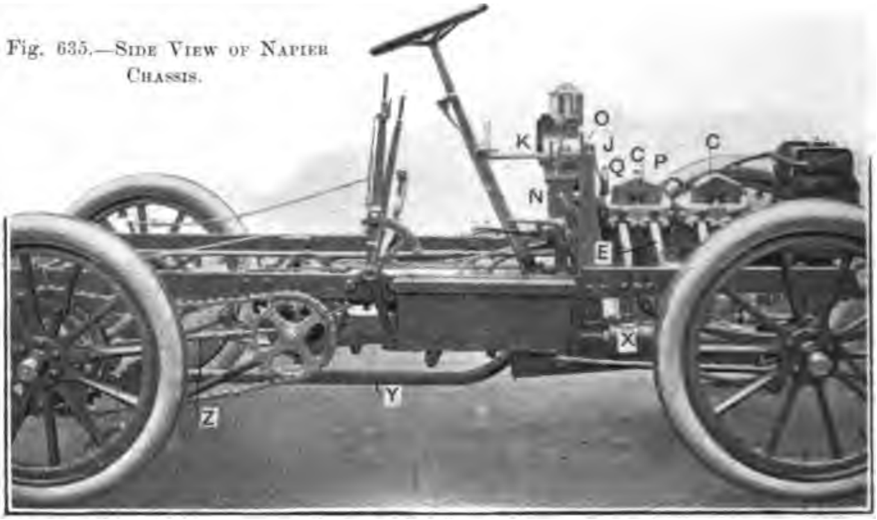


Fig. 635.—Side View of Napier Chassis.

The main frame of the Napier car is either of wood stiffened with steel, or is constructed entirely of channel steel, the motor being carried on an underframe. The suspension springs are long and semi-elliptic. The transmission is on general lines, a strong cone

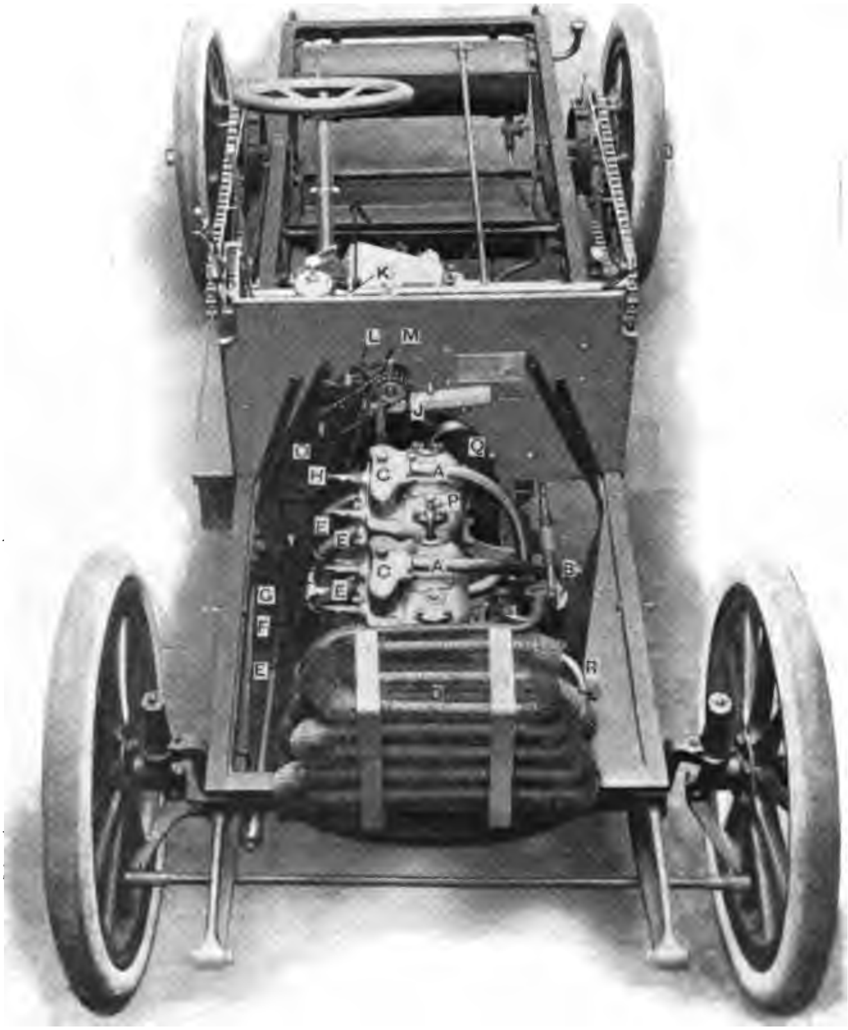


Fig. 636.—Front View, taken from above, of Napier Chassis.

leather-lined clutch driving the change-speed gear, and sprockets on the ends of the countershaft chain-driving the rear wheels. In the gear box the two shafts are practically in the same horizontal plane, the second-motion shaft being, however, slightly higher. The first-motion shaft is of square section, and on it is a sleeve of the same section carrying the fixed gear wheels ; the shaft slides through the sleeve. The sliding spur-wheels are mounted on the second-motion shaft, and this drives the countershaft differential by means of large bevel gearing. Four forward speeds and a reverse are provided, and the aluminium gear box is oil tight and is fitted with a sliding door. The design of the change-speed gear enables the centre of gravity to be kept very low, and the flow is lower than usual. A water-cooled brake on the countershaft differential is actuated by a pedal, a side lever operating the side brakes; all the brakes act in either direction, and application of any one of them withdraws the clutch. A double-ended sprag manipulated from the driver's seat is an additional precaution against running backwards down hills.

The Motor Manufacturing Company's cars (Fig. 637) are in five standard sizes :—8-h.p., one-cylinder ; 7-h.p., two-cylinder ; 10-h.p., two-cylinder ; 12-h.p., four-cylinder ; and 20-h.p., four-cylinder; typical cars being the 8-h.p., 10-h.p. and 20-h.p. The 8-h.p. light car or voiturette has a tubular frame, and the vertical motor, which runs at 1,250 revolutions per minute, has its flywheels forming part of the enclosed, built-up crank-shaft; the bore is 100 mm. (3·93 in.) and the piston stroke 130 mm. (5·12 in.), and there is a special throttle on the inlet valve. Transmission is by side chains. The 10 and 20-h.p. cars have ash frames stiffened with flitch plates, the motor resting upon the side members and the gear-box being secured by angle-iron supports and brackets. The 10-h.p. and 20-h.p. motors are identical except in number of cylinders and size of crank chamber, bore and stroke being the same as in the 8-h.p. car. Near the inlet valves on one side are tubes for lamp ignition, and near the exhaust valves on the other side are plugs for electric ignition. The shaft carrying the exhaust cams is enclosed and is driven by spur gearing through an intermediate wheel from the front end of the crank-shaft. A centrifugal force governor diminishes the intake of mixture. The throttle valves admit cold air to the cylinders when the supply of mixture is cut off entirely, the object being to cool the cylinders. Water is circulated through cylinder jackets and front radiator by a centrifugal pump driven by a friction pulley pressing against the flywheel. In the 20-h.p. car, the water pipe leading from the top of the jacket is a single aluminium fitting. The petrol tank is beneath the front seat and supplies by gravity the float-feed carburetter. All M. M. C. cars have the side chain transmission, and their distinctive feature is the change-speed gear (Iden's design) typified by the arrangement illustrated in horizontal, longitudinal and vertical cross sections by Figs. 638 and 639 respectively. All the shafts, wheels and sleeves are steel drop-forgings. The first and second motion shafts are shown by A and B. A carries on a square part of its forward end (not shown) a clutch cone, and it is rigid with the spur wheels C (14 teeth), D (24 teeth), and E (34 teeth), which always are in mesh with corresponding wheels, F (60 teeth), G (50 teeth), and H (40 teeth), revolving freely on shaft B. In the type of gear employed in the 10 and 20-h.p. cars and here illustrated, the spur wheel J (50 teeth) always engages with an intermediate wheel, K, which in turn meshes with wheel C. In the gear used on the light car, however, the wheel J is rigid with sleeve L, and consequently with bevel wheel M; and the intermediate spur wheel K is brought in and out of mesh with C and J by an eccentric only when required. The spur wheels F, G, and H revolve freely and form bearing surfaces for each other. The shaft B

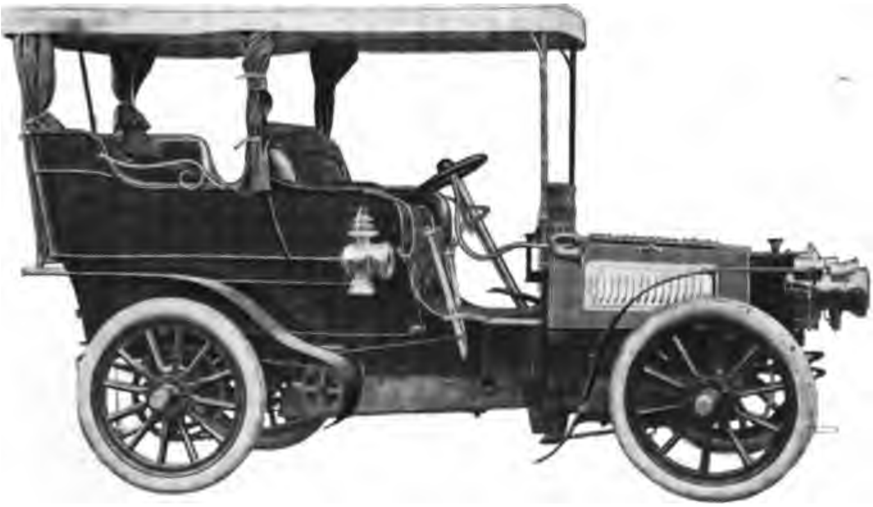
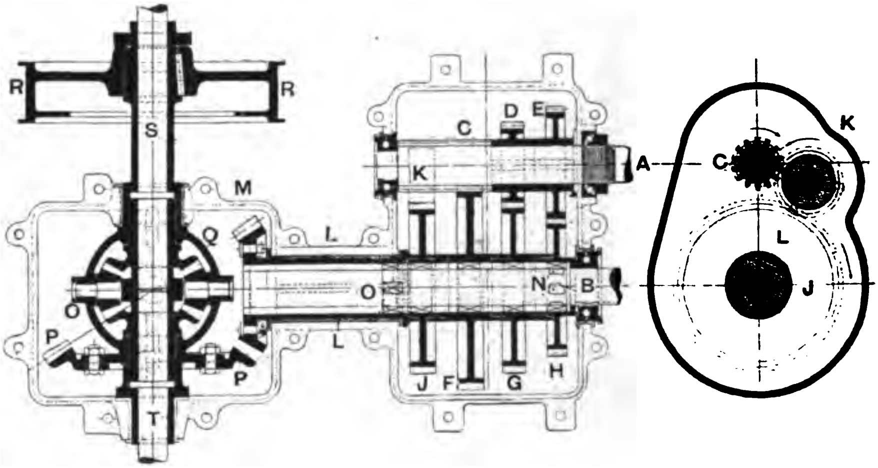


Fig. 637.—MOTOR MANUFACTURING CO.'S CAR.

slides through the hubs of the spur wheels, but projections N on the shaft can be made to engage with corresponding projections in the hubs. Sleeve L has internal slots to receive shaft B and its rear projections O, so that the shaft can slide freely in the sleeve and yet at all times transmit rotary motion to it. Thus shaft A can drive bevel wheel M through any one of the trains at will by sliding the shaft B; M gears with P and so drives the countershaft, on whose outer ends are the driving sprockets. In the light car form of gear already alluded to, the shell of the spur wheel type differential forms a brake drum outside the bevel gear casing, and a separate lever brings the reverse into operation. In the 10 and 20-h.p. cars, the bevel wheel type differential Q is enclosed in the gear case, and a sleeve connects the brake drum R with it. The two half shafts S and T carry the outside sprockets at their ends. Only one lever operates both the three forward and the one reverse speeds. On applying the countershaft brake by pedal or the driving-wheel hub brakes by side lever, the main clutch is disengaged.



Figs. 638 and 639.—Motor Manufacturing Co.'s Change-speed Gear.

The Maudslay car is a new type of English car, whose chief characteristics are accessibility, thorough lubrication, and a roomy and comfortable body, the last-named feature being clearly illustrated by Fig. 640, which is a view of the Maudslay convertible omnibus. Main frame and underframe are of ash-filled, rectangular, solid-drawn steel tubing 44·4 mm. by 50·8 mm. (1·75 in. by 2 in.), and the underframe passes from the front cross piece to the cross member just behind the side sprockets. Tubular stays and side brackets give rigidity to the underframe and connect it to the main frame, they also serving as tie-bars and preventing the frame from twisting. The three-cylinder motor (described in detail on p. 258) with the clutch and change-speed gear is fixed on the underframe, the differential countershaft lies crosswise, and its ends are connected by flexible couplings to the side sprockets, from which the rear wheels are chain-driven; there are the usual adjustable distance rods. Semi-elliptic side springs are fixed to the front and rear axles. One lever operates the change-speed gear, and another the side brakes, these latter being connected by a cross shaft, but not compensated. Two pedals operate the main clutch and countershaft brake respectively; application of either the side or countershaft brakes withdraws the main clutch. The worm and segment steering gear is irreversible, and the steering heads for the front wheels are supported both above and below by the forked ends of the axle. Small hand levers, regulating the motor

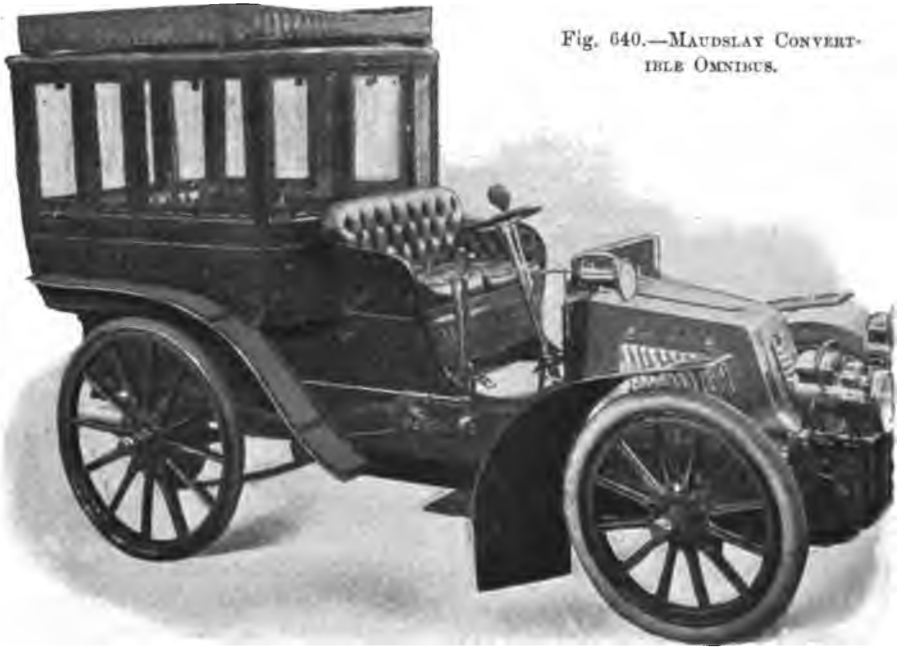
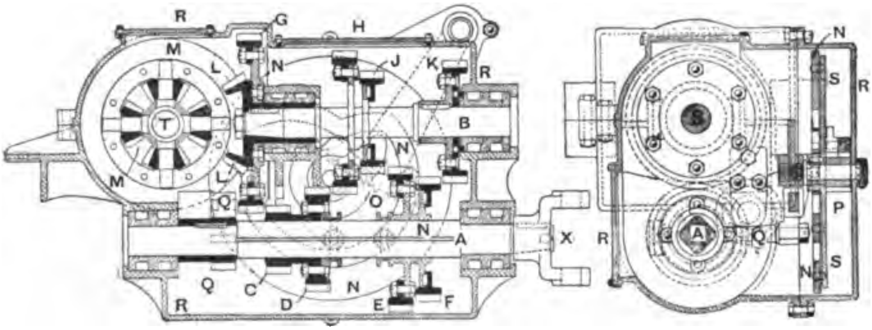


Fig. 640.—Maudslay Convertible Omnibus.

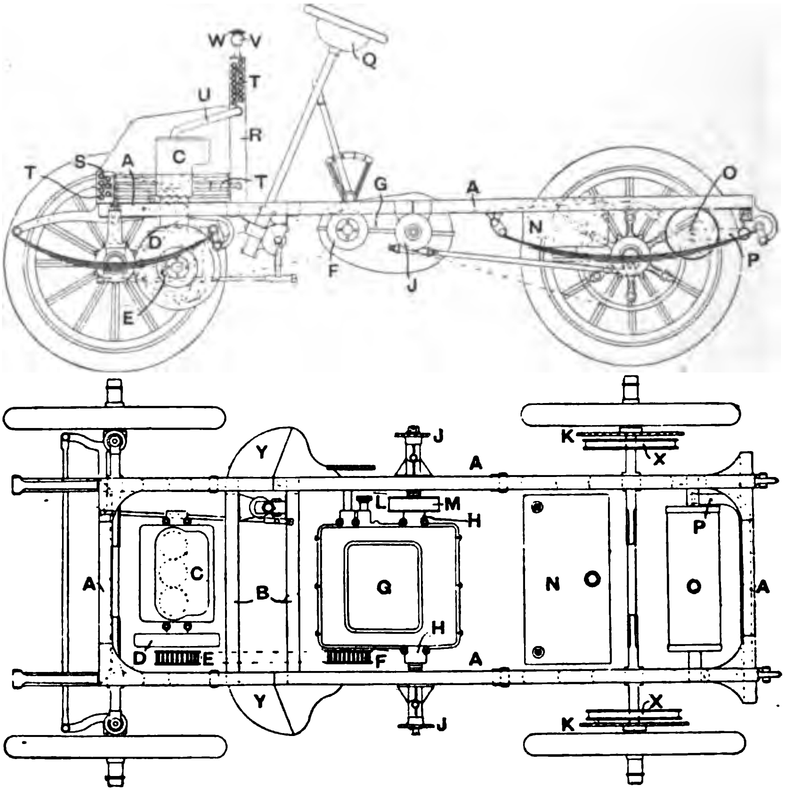
speed by acting upon throttle valve and commutator, are mounted horizontally above the hand steering wheel, the one moving above and the other beneath a toothed quadrant. There are gear-driven lubricating and water circulating pumps in front; and a chain-driven fan is behind the tank radiator. The exhaust box is placed just behind the rear axle.

The Maudslay transmission and change-speed gear may be treated in greater detail. The flywheel has a metal disc which conceals the conical clutch surface formed inside, and enables it to be partly filled with water so as to keep the flywheel cool when making the brake horse-power tests of the motor. The well-designed clutch is large, and normally is held in engagement by an external spring; when held out of engagement a ball bearing takes the thrust. The portion surrounded by a spring forms part of a flexible coupling for a short shaft which connects the clutch through a universal joint, X, Fig. 641, with the first-motion shaft A of the change-speed gear shown in longitudinal and cross section by Figs. 641 and 642. The first-motion shaft beneath the second-motion shaft B, carries on a squared portion two pairs of sliding spur-wheels, C D and E F, and these gear respectively with fixed wheels, G H and J K, on the other shaft B, the largest of the second set G being close to the bevel wheel L, which drives the differential gear M. The shafts revolve in solid brass bushes, which, however, can be replaced by roller bearings. The sliding wheels on shaft A are brought into engagement as required by means of the grooved cam plate N, shown in section by Fig. 642, and partly in solid and partly in dotted lines in Fig. 641; this cam plate is caused to revolve by means of a toothed quadrant O engaging with the spur-wheel P on the cam-plate shaft. The quadrant is carried on a fulcrum pin in the cover of the gear box, and is connected with the change-speed lever, which when moved backwards or forwards causes the cam plate to rotate. In connection with two sliding forks which move the sliding wheels in and out of mesh for the four forward speeds, there are two rollers which ride in the grooved passages in the face of the cam, and thus receive a sliding movement: these rollers and the two forks are fixed to guide pieces which slide on a bar, which itself is also capable of sliding longitudinally when caused to do so by a third roller to which it is directly fixed. The sliding movement given to the first two rollers mentioned is transmitted to the forks, and these bring the different sets of spur wheels into engagement. When the sliding bar itself moves, a third fork slides an intermediate spur wheel Q into mesh with fixed wheel C on the first-motion shaft and with the large gear wheel G on the second-motion shaft. Normally, Q is not in mesh with any wheel. The change-speed lever quadrant, shown in the general view, Fig. 640, is not notched, but is marked to indicate its various positions ; the small catch-lever on the change-speed lever is connected by a Bowden wire with a sliding stop passing through the wall R of the gear box and engaging with large holes drilled in the periphery of the cam plate N, or the holes may be drilled in the steel back plate S of the plate. The stop holds the cam plate in either of its working positions, and ensures that the gear wheels are properly in mesh with one another. The differential countershaft T has a large hollow brake drum between its driven bevel wheel and outer jaw coupling, and there is provision for filling it with water and so preventing it getting too hot. The differential gear has four planetary bevel wheels, as shown. A small pump on the rear end of the first-motion shaft circulates oil round the gear-box bearings.



Figs. 641 and 642.—Maudslay Change-speed Gear.

The Brooke is a British car, thoroughly well built and designed on independent lines. Its special features are a three-cylinder vertical motor (described on p. 254) placed transversely across the frame, a special method of governing the motor by means of the pressure of the exhaust gas (*see* p. 256), the substitution of chains and sprockets for spur gearing (described on p. 396), and the method of equalising the pull upon the side brakes (*see* p. 491). Against the advantage of avoiding sliding spur wheels there are the possible disadvantages of chains stretching, of the jaw clutches employed being less durable than spur-wheel teeth, and the friction of idle but running chains and chain wheels. Figs. 643 and 644 give side elevation and plan of a typical 10-h.p. car. The rectangular channel steel framework A has cross-members, B; in cross-section it is 51 mm. (2 in.) square, and it is filled with ash, the actual thickness of the metal being only 3·17 mm. (·125 in.). C shows the three-cylinder motor, and between its fly-wheel D and the chain wheel E is a leather-lined clutch, having a ball thrust and operated by a pedal. A Renolds chain passes from E to the other chain wheel F, which drives the first-motion shaft of the change-speed gear G (described on p. 396). H is the differential countershaft which by sprockets, J, chain-drives sprockets, K, on the rear wheels. L is the toothed



Figs. 643 and 644.—Elevation and Plan of Brooke Car.

wheel worked by the controlling quadrant. There is a water-jacketed band-brake drum, M, outside the gear case. In the tank N, carried under the body, petrol spirit is kept under a slight air pressure, which is maintained by the work done by the driver's foot upon the accelerator pedal. Of two other pedals, one operates a rocking shaft controlling the main clutch, and an ingenious brake on the outside sprocket wheel on the first-motion shaft, whilst the other works brake M and also operates the main clutch. The exhaust box O, underneath at the rear, is made of sheet iron, with aluminium ends, and contains perforated baffle plates; from it passes a pipe, P, containing perforations. On the motor exhaust pipe is a valve (*see* p. 204) opened at will by the driver to relieve back pressure if it occurs to any great extent, and to listen to the exhaust and thus ascertain how the motor is working. The steering wheel Q forms a basin in which the driver can place small articles. The water circulation is natural. The radiator has cast aluminium upper and lower headers, R S, joined by Clarkson tubes, T, which merely slip into sockets and are tightened with rubber rings; in practice leaks do not occur, and the method prevents the vibration from fracturing the tubes. A double pipe, U, passes through the aluminium top plate from the motor. The upper headers R are also connected by tube V, carrying a central spiral fitting, W, acting as the filler to the water system from above, and providing a vent to a drain pipe beneath; 9 l. (2 gal.) of water is carried. There are band brakes on the side drums X. On the dashboard is a multiple feed lubricator, consisting of a box divided into eight compartments, each having a gauge glass to show the level of the oil within, and from each of which there is a separate adjustable pipe feed; the box is filled through but one opening. The four 91·4 cm. (36 in.) artillery road wheels have Continental or Michelin tyres. The chassis weighs only 762 kg. (15 cwt.), and the usual body is of the tonneau type, the dash having cupboards, Y, for batteries and tools.

The Brooke new 14-h.p. car has a three-cylinder motor, with mechanically operated inlet valves, fixed longitudinally beneath the bonnet; and instead of a governor operated by the pressure of the exhaust there is a combined governor and carburetter which controls the motor speed by the piston suction. The principle of the appliance is based upon the fact that the pressure in a carburetter mixing chamber is less than that of the atmosphere when the motor is working, and that the degree of vacuum produced varies with the speed of the motor. A multitubular radiator in front has a fan behind it. The weight is 762 kg. (15 cwt.) and the speed may exceed 72·4 km. (45 miles) per hour. The wheel base is 2·29 m. (7 ft. 6 in.), the track 143·5 cm. (4 ft. 8·5 in.), and the Dunlop-tyred wheels are 76 cm. (30 in.) in diameter. The frame is of wood, but in future will be of stamped steel.

Ader cars are of 8, 12, and 16–18-h.p., the last-named having a four-cylinder motor and the others a two-cylinder. Ader motors are dealt with on p. 271. The Ader car is one of the few that now use a surface carburetter; between it and the induction valves is a throttle valve regulated by the governor. The frame is tubular, there is no underframe, and the gear box is supported at the back by the countershaft and is secured in front by a swinging link to the frame. A side lever whose shaft passes direct into the gear box operates all the four forward speeds, and there is a separate lever for the reverse. The drive is by means of countershafts and side chains. The Ader clutch and change-speed gear are described on pp. 371 and 394.

Beaufort cars may be noted. The new models are 8, 9, 10, 14, and 20-h.p. respectively. All have channel steel main frames, artillery wheels, vertical motors, and magneto ignition; and all of them, the 8-h.p. excepted, have water circulation pumps driven by gearing running in an oil bath; the exception has the thermo-syphon circulation. The 8 and 9-h.p. motors are single-cylinder, the 10 and 14-h.p. are twin-cylinder, and the 20-h.p. is four-cylinder, and all have mechanically operated inlet valves with the exception of the 8-h.p. motor. The 20-h.p. car has the Simplex variable speed gear, and the transmission is by countershaft and side chains; all the others have spur-wheel change-speed gear and transmission by longitudinal shaft and live rear axle. The 8-h.p. car and the 9-h.p. phaeton have two forward speeds; the 9-h.p. tonneau and the 10 and 14-h.p. cars have three forward speeds, and, of course, all have a reverse. A special form of radiator used on the higher-powered cars has three or four hundred plain copper vertical tubes arranged in eleven rows forming a rectangle in plan, the tubes connecting top and bottom reservoirs.

The Belle voiturette or light runabout car is of Swiss manufacture. A dropped frame fixed to the main frame carries the motor. The 8-h.p. vehicle has a tonneau body, and its single-cylinder motor is placed at an angle of 45° from the vertical, its crankshaft lying across the car in front, and the power being transmitted by a chrome-tan leather belt with a canvas core. The belt runs upon fast and loose pulleys on a first-motion cross shaft, and the side chain drive is from sprockets on the ends of the second - motion differential countershaft. The change-speed gear on the Panhard system gives three speeds and a reverse. The steering pillar is placed centrally to allow of the driver dismounting on either side of the car. A surface carburetter is used.

Brush cars of 8, 12, and 16-h.p. are the products of a well-known British firm. Except, of course, in size and power of motor the cars are alike in their essential features, and Fig. 645, showing the 16-h.p. chassis, gives a good idea of them all. This has a four-cylinder motor (*see* p. 229), a gravity-fed float-feed carburetter, and the water is cooled in a Loyal multitubular radiator of distinctive shape. A double-trembler induction coil is used with a current having an E.M.F. of six volts, and

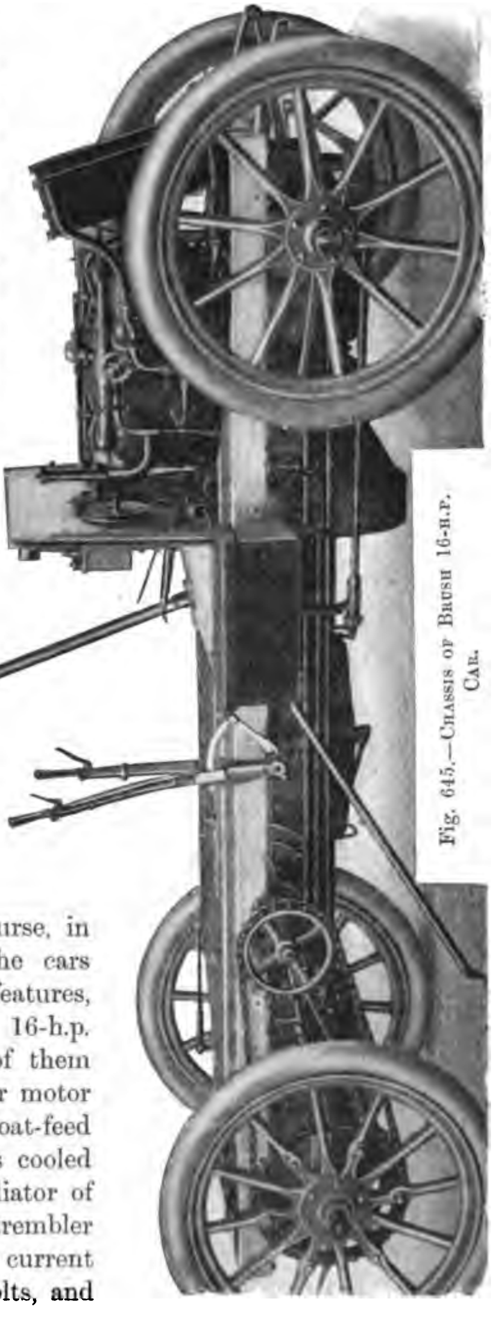


Fig. 645.—Chassis of Brush 16-h.p. Car.

in the diagram of electrical connections, shown by Fig. 646, A is the accumulator, B the coil, C the commutator, D the ignition plugs, E the connections to frame, and F the switch. The main frame is of wood, stiffened with steel plates. The Panhard type sliding change-speed gear is controlled by one lever for both forward and reverse. The drive is by side chains from the differential countershaft. Brakes are double-acting, axles are Lemoine or Bail-Pozzy, and there are four equal artillery wheels with pneumatic tyres. On the steering column are two levers, one regulating ignition and the other operating the throttle on the induction pipe.

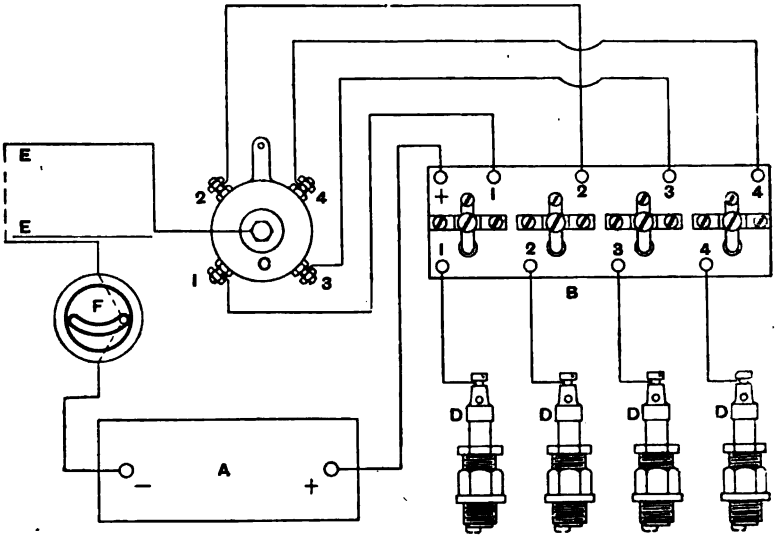


Fig. 646.—Brush Electric Ignition System.

The Canterbury 12-h.p. car has a wood and flitch frame and an angle steel underframe, the latter carrying the two-cylinder Astor motor and gear box with ball bearings. The differential gear on the countershaft is outside the gear box, and transmission is by side chains; the driving sprockets are rings with four arms registering over the fixed hubs, and each held in place by four bolts, and so can be removed without interfering with the hubs. The reverse of usual practice, the side brakes are operated by pedal, and the countershaft brake by side lever, a similar arrangement being found in the Phœnix 12-h.p. live rear axle car, which has a two-cylinder motor, and gives three forward speeds and a reverse.

The Charron, Girardot and Voigt 20-h.p. car with four-cylinder motor has a main frame of square-section tubing filled with ash, supported on semi-elliptic springs; the projecting horns of the front springs are tied together by a cross bar, and the rear ends of the rear springs are carried by an inverted transverse spring. Fig. 647 shows the chassis of this car. There is no underframe, and the special steel cylinder motor is fixed to the main frame by four feet projecting from the upper casting of the crank chamber. The two cam shafts operating both inlet and exhaust valves lie one on each side of the crank chamber, the cams themselves being encased. Spiral gears drive the lubricating and water circulating pumps. The high-tension ignition plugs are fixed horizontally into the valve chambers immediately above the inlet valves. The main clutch, of the band-brake type, drives the change-speed gear through a universal coupling, the gear itself resembling the Mors and Ader systems. There are four forward speeds and a reverse. Couplings between the differential gear and outside ball bearings give flexibility to a cross countershaft upon whose ends are the sprockets which drive the rear road wheels. The strain imposed upon the compensated and expanding side brakes when in use is transmitted directly to the very prominent distance rod (*see* Fig. 647) which connects the back axle with the frame, and so serves to tighten the side driving chains. The C. G. V. 40-h.p. eight-cylinder car generally resembles the above. The motor is fixed to the frame by six feet. There are two carburetters, one for each four cylinders, and the exhaust gases for each four are led away by a single pipe connection passing across the ports through which the gases leave the cylinders. The object is to dispense with change-speed gear (*see* p. 252), but the arrangement is only partially successful in this respect.

The Chenard and Walcker cars are remarkable for the means adopted for controlling the motor (described in detail on pp. 237–241), and for the special electric ignition system (p. 182). The main frame of wood, stiffened with steel flitch plates, supports a short underframe of angle section steel, which carries the motor. The frame is suspended by long and flat semi-elliptic springs above the front and rear axles, and the rear axle is also connected with the frame by pivoted distance rods. The artillery wheels are of equal size, and have Clipper-Michelin tyres, the wheel base being about 216 cm. (6 ft. 3 in.). The steering gear is of the wheel type, with irreversible worm and worm-wheel. The steering pillar is perfectly plain, and does not carry any regulating levers. The hubs of the rear wheels are provided with brake drums of large diameter and width, around which double-acting brake bands are fitted. The rods actuating the brakes are attached at either end of a cross beam, which is free to slide in horizontal slots in the frame. There is a special combined main clutch and brake (described on p. 496), and transmission is by side chains from a cross countershaft. Three forward speeds and a reverse are provided, the top speed being a direct-through-drive from the clutch shaft to the small bevel wheel driving the differential gear. The direct connection through the box is made by a jaw clutch, and the front portion of the shaft carries a spur wheel, which is at all times in mesh with a corresponding wheel on a lay shaft mounted above the other shaft. The sliding wheels only are carried upon the squared portion of the direct-through-drive shaft, and the reverse is provided by an intermediate pinion, which is in mesh with the rear wheel on the lay shaft. The reverse speed is obtained when the gear lever is in its foremost position. The lever is moved towards the driver for bringing higher speeds into play. The differential has bevel planet wheels. Lubrication of all parts is effected from a single lubricator fixed to the dashboard, the oil contained in it being kept under pressure by a pipe leading from the exhaust pipe. The petrol tank, which contains 20·4 l. (4½ gal.), is fixed beneath the front seat. The water tank is fixed immediately in front of the dash, and a centrifugal pump, friction-driven from the flywheel and attached to the underframe, circulates the water from it through the radiator in front and through the jackets. Circulation is natural should the pump fail to work. The car appears to be a good hill climber, and the fact that the reverse gear gives a considerably lower speed than the first forward speed, allows unusually steep hills to be mounted by travelling up them backwards, a fourth gear being thus practically available. The complete weight of the car is about 700 kg. (13·78 cwt.). The dimensions over all are: Length, 3 m. (9 ft. 10 in.); width, 1·55 m. (5 ft. 1 in.), and height, 1·52 m. (5 ft.).

The de Dietrich (Turcat-Méry) main frame is of wood, strengthened with steel plates and tie rods and with iron angle plates. An underframe carries the four-cylinder motor (some cars have two cylinders only), for which see p. 249, this having the carburetter described on p. 135, and magneto ignition. The carburetter's supply of mixture varies according to the speed of the motor, the means assuring this also allowing of the motor acting as a pneumatic brake when running down hill. The change-speed gear giving four speeds and a reverse is described on p. 394. There is a metal-to-metal brake on the cross differential shaft whose ends carry the driving sprockets, and there are double-acting band brakes on the rear wheels.

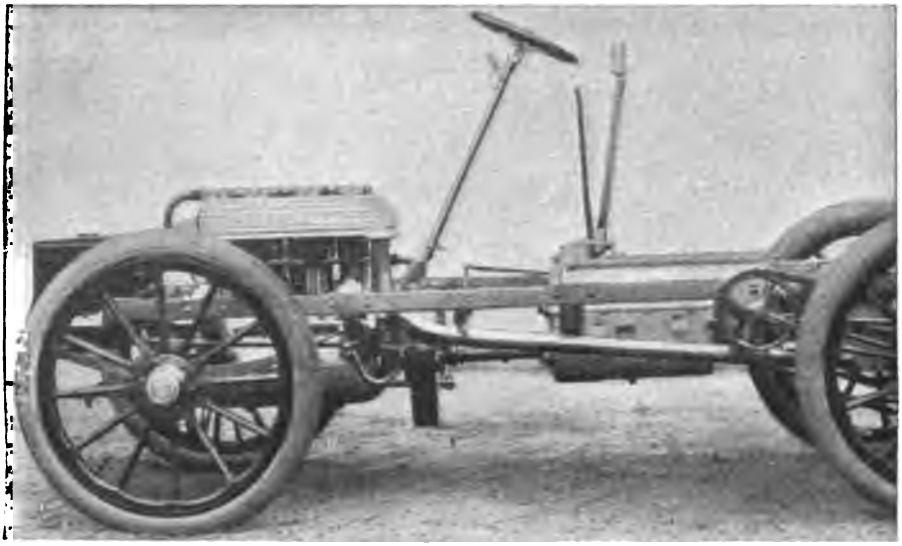


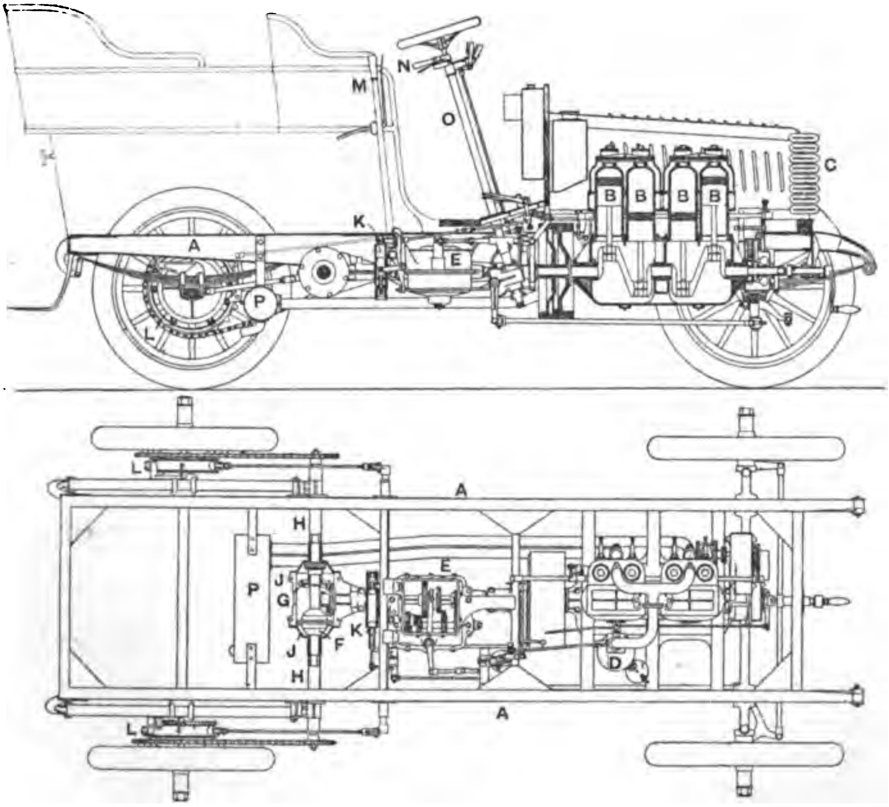
Fig. 647.—Charron, Girardot, and Voight Chassis.

Delahaye cars may have a one or two cylinder horizontal motor or a two or four cylinder vertical motor, and the transmission system of the first type is described on p. 418. Of the two cars with vertical motors the larger one has its radiator forming the front of the bonnet, and the smaller one has its radiator suspended in front of the front axle. Figs. 648 and 649 show the 25–28-h.p. four-cylinder car. The main frame A is of stamped steel, and there is no underframe. B shows the motor cylinders under the bonnet, with the radiator C in front. D is the carburetter. The change-speed gear E is enclosed in a casting fixed to two cross members of the frame, separate from the differential gear F and from the bevel gear G driving the countershaft H; the casing J is supported by tubes enclosing the two halves of the countershaft. Side chains drive the rear wheels. A band brake, K, between gear box and differential casing, is applied by a pedal, and there are the usual side brakes, L, operated by side lever M. The sprag for preventing the car running backwards is replaced by a pawl and ratchet device; a ratchet wheel is fixed inside the brake drum of the right-hand driving wheel, and a pawl can be made to engage with it. Speed-changing is operated by a horizontal lever, N, mounted on the steering pillar O. The exhaust silencer is shown at P.

Titan motors, employed on Delahaye cars, are of two chief kinds, horizontal and vertical; the 8½-h.p. to 9-h.p. horizontal motor has one cylinder of 110 mm. (4·33 in.) bore and 140 mm. (5·5 in.) stroke, its speed varying between 900 and 1,200 revolutions per minute. Another horizontal motor has two cylinders, of the same bore and stroke as the other, its power being from 13½ to 14 h.p., at a speed varying from 900 to 1,400 revolutions per minute. Of the vertical motors, the two-cylinder type has precisely the same dimensions, speed, and power as the two-cylinder horizontal; the four-cylinder vertical motor also has the same dimensions and speed, but its power is from 25-h.p. to 28-h.p. Each type of the vertical motors approaches to what has almost become standard practice, its points being that it has feet resting upon the sides of the underframe, its inlet valves are atmospheric, the circulating pump is spur-gear-driven, and the timing rod for the high tension ignition is connected with half-compression cams which relieve the cylinder pressure when starting, and are brought into play when the spark is retarded to its earliest position. The cylinders are connected in pairs to the exhaust box, which is just in front of the back axle. The carburetter is of the constant level spraying type, and is fitted with paddles to make the mixture of air and spirit more intimate; it works with petrol spirit, alcohol, or carburetted alcohol.

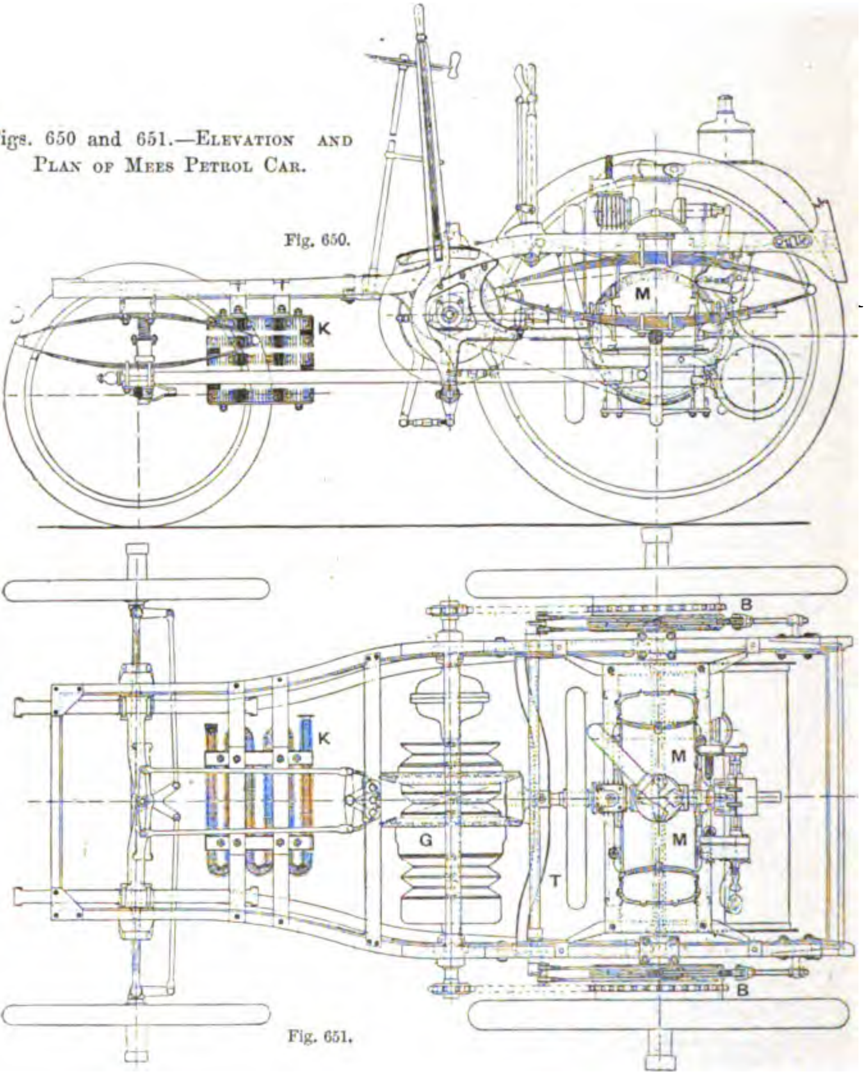
The Dèschamps two-cylinder cars are of 7-h.p. and 9-h.p., and the four-cylinder cars of 14-h.p. and 18-h.p., the motor speed being 850 revolutions per minute normally, and 1,100 revolutions when a 30 per cent. increase in the output is wanted for a brief period. The bore and stroke of the 7 and 14-h.p. motors are 95 mm. and 150 mm.

(3·74 and 5·9 in.), and of the 9 and 18-h.p. motors 100 mm. and 130 mm. (3·93 and 5·1 in.). The Creese self-starting device fitted to the motors causes the passage of an electric spark in whichever cylinder is necessary to drive the motor in a forward direction. The ignition plugs are screwed into vertical tubes connected by bends and nipples with the combustion chamber instead of being screwed direct into the cylinder casting, the object being to reduce risk of pre-ignition, and to prevent undue racing when in the hands of novices. The three-piece crank chamber has upper and lower castings of aluminium, and the middle one, providing the crank-shaft bearings, of gun-metal. The general design of the car is on Panhard lines. Transmission is by countershaft, having flexible couplings, and



Figs. 648 and 649.—Elevation and Plan of Delahaye 25-h.p. Car.

side chains; on the countershaft is a double-acting metal-to-metal brake applied by pedals. There are four forward speeds and a reverse. A special feature is the method of applying the bands to the brake drum on the rear hubs. A side lever is fixed to a cross shaft on whose two ends are bevel-wheel segments engaging with small bevel wheels mounted on the forward ends of two shafts; these



Figs. 650 and 651.—Elevation and Plan of Mees Petrol Car.

shafts tighten or loosen the brakes according to how they are rotated, the threaded ends of the brake bands riding on left and right hand threads cut on the shafts.

The F. I. A. T. 20-h.p. car (Italian) is a new model whose four-cylinder motor with mechanically operated inlet valves is described on p. 253. The motor is carried by an underframe suspended from the main frame of wood and steel, whilst the spur-wheel change-speed gear is supported by tubes which enclose the countershaft, and which are fixed to the main frame. The transmission is by side chains. The brakes on the rear wheels are double-acting and of the compensated internal type. The suspension springs are very long and semi-elliptic, and the rear axle is of **H**-section. A honeycomb radiator forms the front of the bonnet, behind it being a motor-driven fan.

Gladiator cars are of three principal kinds:—6-h.p., one-cylinder; 10-h.p., two-cylinder; and 12-h.p., four-cylinder. The last named has a neat motor, with its cylinders cast in pairs and atmospheric inlet valves, fixed with the change-speed gear box to an angle steel underframe supported by a main frame of wood strengthened with flitch plates. Behind a honeycomb radiator is a belt-driven fan as usual. There are four forward speeds and a reverse, and transmission is by side chains from a countershaft. A ratchet and pawl replace the usual sprag (see the description of the Delahaye car on p. 604). The 10-h.p. car has a similar transmission, the gear giving three forward speeds and a reverse.

The Mees car obtained at the 1899 Exhibition in Berlin a gold medal for excellence in design and construction. An elevation of the four-year-old type is given by Fig. 650, and a plan and back view by Figs. 651 and 652. The motor is shown by Fig. 247, p. 262. The bent wood car frame is braced with steel gussets and ties, and rests through elliptical plate springs on two axles, which are tied together further by two longitudinal steel tubes; the motor and intermediate gear are suspended from this framework, the encased motor being secured by two springs to the rear axle, as shown by M. The petrol tank, which is also the carburetter, is shown at E, and the cooling water tank at W. In the carburetter is a coil through which part of the exhaust gases are led, air being admitted through a small chimney. The motor shaft lies in the longitudinal axis of the car, and at its inner end carries a small bevel pinion which engages with two larger wheels on the intermediate shaft.

shown in Fig. 651, and in enlarged detail by Fig. 653. This intermediate shaft carries a differential gear and a variable speed gear, and at each end, outside the car frame, a pitch chain pinion driving the rear wheels in the usual manner. Each driving wheel carries a brake drum, B, round which is a coil of steel wire rope, both brakes being tightened simultaneously by operating one brake lever. The principle of the power transmission and speed changing is that of the "sun and planet" gear. Letter references in Figs. 650 to 652 remaining to be described are: T, motor fly-wheel; G, wheels, etc., on intermediate shaft; K, radiator.

Fig. 652.

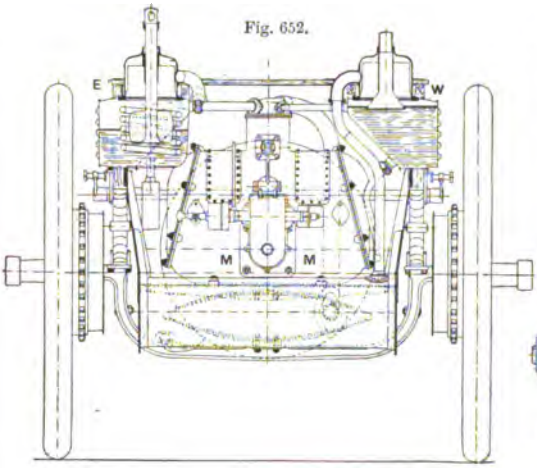
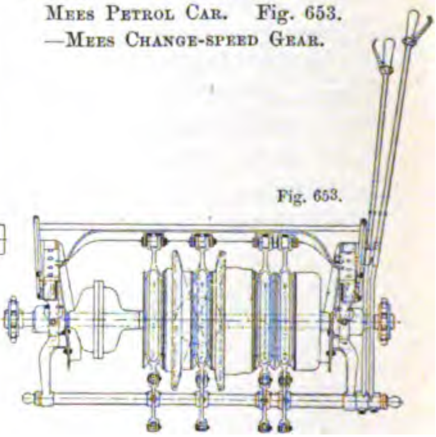


Fig. 652.—Rear Elevation of Mees Petrol Car. Fig. 653.—Mees Change-speed Gear.

Fig. 653.



The Korte two-cylinder 12-h.p. car has the crank-shaft lying crosswise with the main clutch on its left end; from it a Renolds chain drives the change-speed gear, giving four forward speeds and a reverse, and the final drive is by side chains.

One type of Milnes car (it is nominally a voiturette) has a two-cylinder vertical motor fixed direct to the channel steel rectangular main frame A (Figs. 654 and 655). The motor has mechanically operated valves, and is described in detail on p. 232. The front part of the frame is slightly narrower than the back part. The suspension springs are semi-elliptic, and there are the usual distance rods between the back axle and the main frame. B shows the two cylinders cast in one piece, and C is the big flywheel forming the shell of the main clutch, whose male portion is secured to a sleeve, D, mounted about the forward end of the first-motion shaft. This shaft does not move longitudinally, and its extreme forward end forms a steadying spigot; it is made in two parts, one carrying the sliding wheels inside the gear case E, and the other carrying the clutch sleeve, and the two parts are connected by a flange coupling, which has a distance piece between the two flanges, so that the clutch can be taken out without disturbing the gear box. The clutch spring at D has a ball thrust, against which

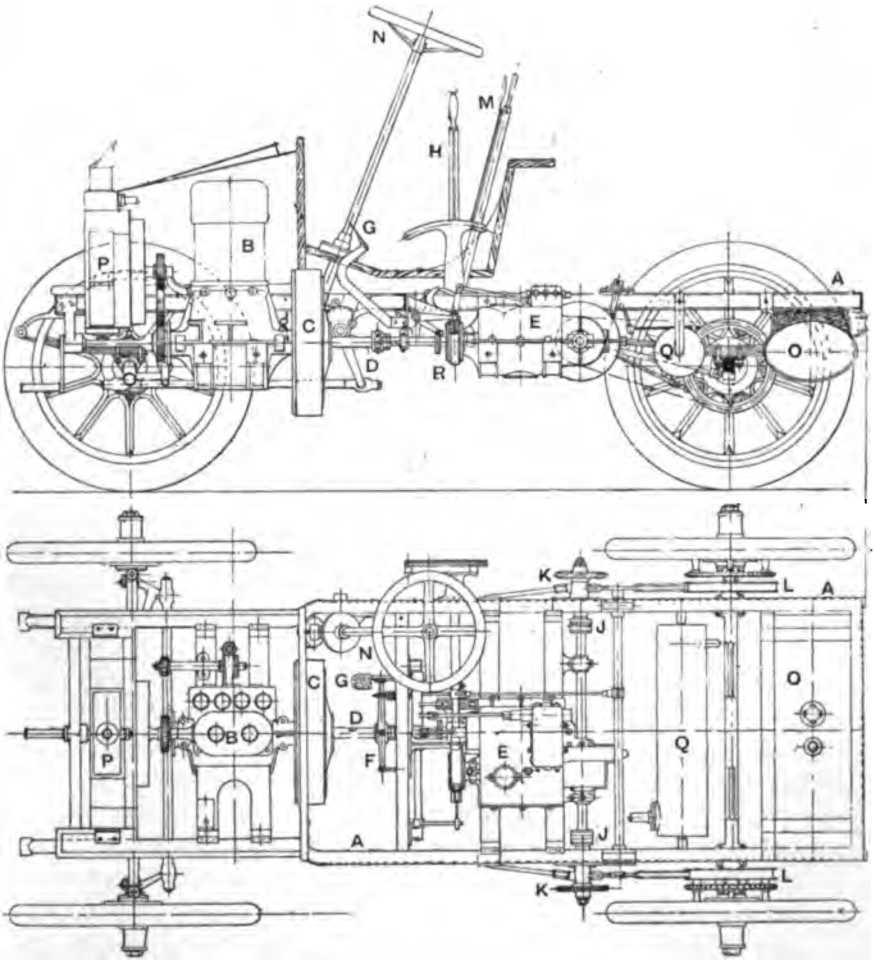


Fig. 654 and 655.—Elevation and Plan of Milnes Voiturette.

presses the operating lever F; this lever is horizontal and is pivoted at one end, and has a spring and pedal, G, at the other. The Mercedes-Milnes gear box is described and illustrated on p. 390. The sliding spur wheels on the first-motion shaft are controlled by one rod, and the intermediate "reverse" pinion by another; but both of these rods are jointly operated by one lever, H. J shows the flexible couplings on the countershaft referred to on p. 390, and K is the side chain-driving sprockets. The double-acting side brakes L have a compensating cord connection, and are each connected by a stay with the countershaft bracket on that side, much of the strain being in this way transferred to the frame; they are applied by hand lever M, the main clutch being automatically disengaged. The steering gear has adjustable ball-socket joints, and stops on the steering heads limit the turning of the wheels. N shows the inclined pillar. A combined hand and foot accelerator is fitted, the hand lever being mounted on the steering pillar and working in a quadrant; it adjusts the normal speed of the motor. The lever is connected through an enclosed spring with a pedal, and on depressing this the governor is cut out entirely. The lubricating oil tank is fitted in front of the dashboard beneath the bonnet, and pressure is maintained in it by the same pressure valve that causes the exhaust gases to keep a pressure on the oval-section petrol tank O. The lubricating oil is led by a pipe to a fitting on the right-hand side of the dash, from which adjustable feeds lead to the two cylinders and to the two bearings of the crank-shaft. In the centre of the dash is an entirely distinct lubricator, from which oil is pumped into the crank chamber. The change-speed gear bearings are lubricated from a multiple-feed oiler fixed on the left-hand side of the dash, four adjustable feeds being provided by it. The Mercedes combined water tank and radiator P is fixed across in front, and its lower portion is laminated to give a large cooling surface. The exhaust box Q is fixed between the change-speed gear and the back axles. The band brake in the transmission gear is shown at R.

The Morris 10-h.p. car, with channel steel main frame and underframe, has a two-cylinder motor, and transmission is by side chains. The male portion of the main cone clutch slides upon the first-motion shaft and drives it by three feather keys. The second-motion shaft is above, and the differential gear on the countershaft carries two bevel wheels brought alternately into mesh with the wheel on the rear end of the second-motion shaft by sliding the differential sideways. There are internal expanding brakes inside the countershaft driving sprockets and in the rear wheel hubs.

Mors cars are produced in many styles, Fig. 656 showing a handsome construction similar to the Maudslay car, Fig. 640, p. 593, but the leading models at present are the 11 and 18-h.p. respectively. The latter being typical is here described. The frame A, Figs. 657 and 658, is a fine example of steel stamping, and the peculiar construction at the front ends will be noted. The ends B project downwards and form the front horns for the springs C, and they are connected by a rod, D, passing across in front of the honeycomb radiator E, behind which is a fan, W. Owing to the use of drop axles the frame is carried low, the countershaft F, from whose sprockets, G, the rear wheels are chain-driven, being on the same level as the crank-shaft H, and only slightly higher than the wheel hubs. The rear axle is of **H** section, and the front axle is bowed downwards to clear the motor J, which is fixed direct to the main frame, no underframe being employed. The horns K supporting the springs L at the rear are separate forgings and project considerably. The four-cylinder vertical motor is of a thoroughly up-to-date design (*see* p. 233) and has mechanically operated valves; its carburetter, M, is described on p. 126. The hand levers N for regulating ignition and throttle are mounted on the hand steering wheel, and are connected with the mechanism through the hollow

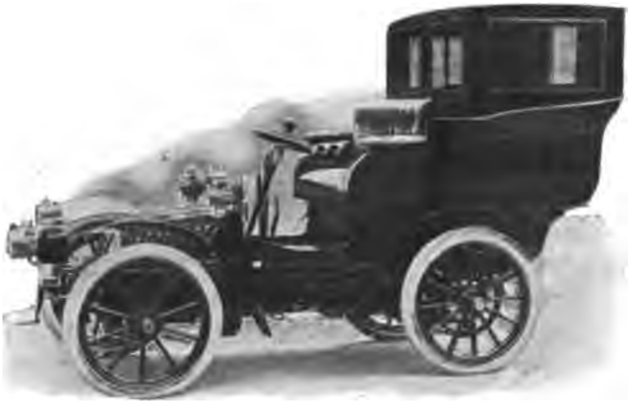
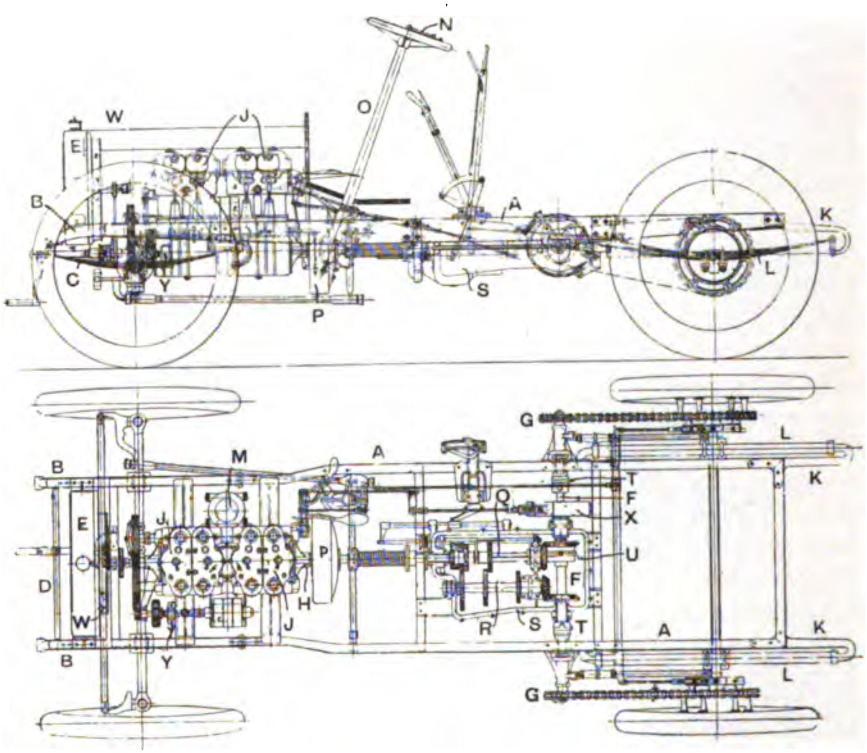


Fig. 656.—Mors Car.

steering pillar O; this method abolishes all small levers on the pillar, and so improves appearance and better suits the driver's convenience. P is the flywheel clutch. The change-speed gear (described on p. 392) gives a direct through drive on the top speed through shaft Q, and the bevel gears shown; at lower speeds the drive is through shaft R. The two-piece gear box S is fixed at each end to drop brackets forming cross members of the main frame. There are flexible couplings, T, at each side between the differential U and the side sprockets G. Separate exhaust pipes lead from each cylinder, and each pair comes together on its way to the exhaust box, which is behind the change-speed gear. There are the usual countershaft brake, X, and side brakes. The water circulation pump Y is driven by the motor.

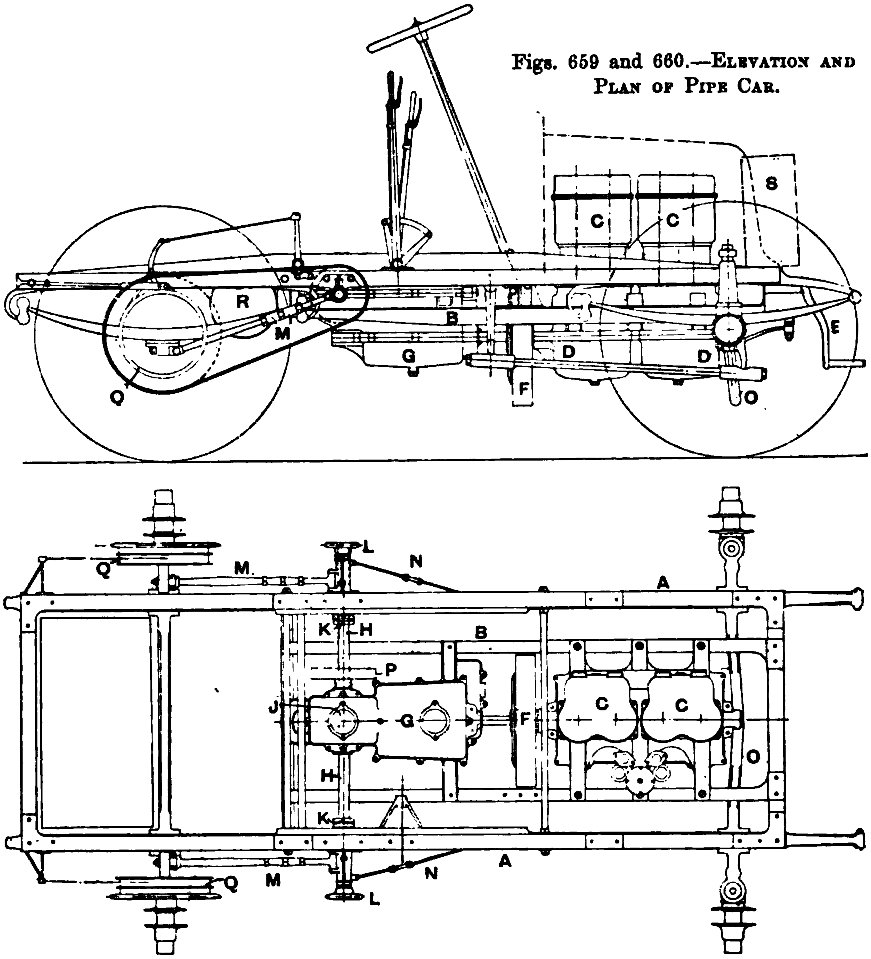


Figs. 657 and 658.—Elevation and Plan of Mors Car.

Peugeot cars are thoroughly representative of French up-to-date practice. They are made in many powers, the standard cars being of 18 and 12-h.p. with four cylinders, 10-h.p. with two cylinders, and 6½-h.p. with one cylinder. The 12-h.p. and 18-h.p. cars each have a special steel frame, and an underframe, carrying the motor, passes from a substantial cross-member behind the flywheel and joins the main frame in front. Peugeot motors are described on p. 235. There is a gear-driven magneto and a honeycomb radiator with fan. A cone clutch in the flywheel transmits the power through a flexible coupling to the gear box in which the two shafts are arranged in one horizontal plane. Tubes passing from the gear box to the main frame hold the box in place and enclose the shafts connecting the differential gear with the outside sprockets, the final drive to the wheels being by side chains. In the two-piece gear box, which has a removable top inspection plate, is a metal-to-metal band brake applied by a pedal. The centre of gravity is kept low by attaching the long rear springs to upwardly projecting brackets fixed to the frame and by employing a low front axle.

The Pipe, a Belgian car, has a wooden frame A (Figs. 659 and 660) strengthened with steel flitch plates and lightened with perforations. An underframe B of two members bent up in front to join the main frame and carried at the rear on a cross member, supports the motor C and change-speed gear. Each pair of cylinders in the four-cylinder motor is cast together, the jackets, heads, and valve chambers being in one piece with them. A very accessible inlet valve is arranged above each cylinder. The exhaust valves are at the left of the cylinders, the high-tension ignition plugs being opposite them. The cylinders are bolted to the top of the aluminium crank chamber D, and the gear wheels driving the cam shaft are partly enclosed in a light casing. The starting handle E is connected with the crank-shaft through a chain and one-way clutch. The governor is on the hit-and-miss principle and operates a throttle in the induction pipe. The motor drives through the main friction clutch F the Panhard type change-speed gear, whose box G is in three pieces, the joints between each passing horizontally through the bearings of each shaft; the middle casting carries the second-motion shaft and countershaft, and the lower casting the first-motion shaft, and the intermediate pinions for the reverse. The countershaft H carries an enclosed differential J, and its two halves have flexible couplings K, the sprockets L, which chain-drive the rear road wheels, being on the extreme ends. The outside brackets supporting the countershaft are connected to the rear axle by the usual distance rods M, and are tied to the main frame by forward stays, N. Suspension springs are semi-elliptic, and the axles are substantial forgings, the front one O being bowed forward and downward to clear the motor. A pedal operates a double-acting band brake P on the countershaft, and the side band brakes Q, applied by a side lever, are compensated by a connecting steel wire. The water tank at the rear is shown by R, and the front radiator by S.

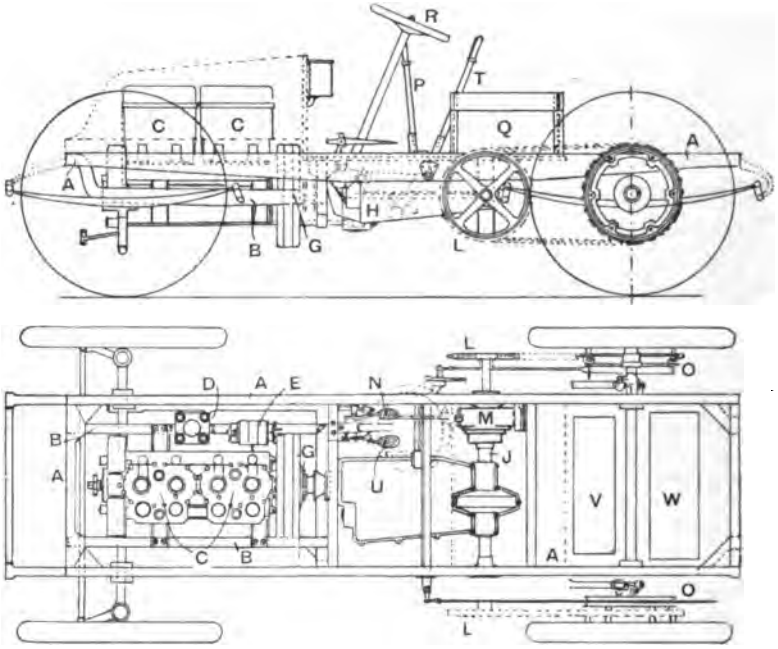
Georges Richard cars are of four principal sizes: (*a*) The 10-h.p. car has a two-cylinder motor of 100 mm. (3·93 in.) bore and stroke, an encased circular governor acting on the throttle on the top of the motor; there are three forward speeds and a reverse, and there is a direct through drive on the top speed, a longitudinal shaft driving a live rear axle through bevel gearing. There is a flexible coupling between motor and gear box. The frame and underframe are tubular, wheels are artillery, 75 cm. (29·5 in.) in diameter, and the wheel-base is 1·93 m. (76·5 in.), the track 124·5 cm. (49 in.), and the total length of car 3·05 m. (10 ft.). The chassis alone weighs 483 kg. (9·5 cwt.), and with an ordinary body about 584 kg. (11·5 cwt.). (*b*) The 12-h.p. car has a similar motor, but the bore is 104 mm. (4·09 in.), the stroke 100 mm. (3.93 in.), and the brake. h.p. is 13. Ignition is by rotary magneto. There are four forward speeds and a reverse, the artillery wheels are 80 cm. (31·5 in.) in diameter, and the chassis and car are respectively 50·8 kg. (1 cwt.) and 101·6 kg. (2 cwt.) heavier than in the 10-h.p. car. The wheel-base is only slightly longer, and the track and length are about the same. Other details are much as before. (*c*) The 24-h.p. car has a four-cylinder motor of 104 mm. bore and 100 mm. stroke. The wheels are 87 cm. (34·25 in.) in diameter, the wheel-base is 2·26 m. (7 ft. 5 in.), the track 129·5 cm. (51 in.), the length 3·35 m. (11 ft.), the weight of chassis 686 kg. (13·5 cwt.), and the weight of an ordinary car about 838 kg. (16·5 cwt.). (*d*) The 40-h.p. car differs from all the others in having side chain transmission, and a reinforced ash or special taper steel frame instead of a tubular frame. Figs. 661 and 662 are diagrammatic elevation and plan of the 40-h.p. chassis. The frame, A, has well cambered steel flitch plates running outside for the whole length. A channel steel underframe, B, carries the four-cylinder motor C, of 125 mm. (4·92 in.) bore and 130 mm. (5·1 in.) stroke. The special carburetter used, D, is described on p. 127. A rotary magneto, E, is driven off a separate lay shaft on the right of the motor; this shaft also drives the force feed lubricating pump in the lubricating tank. The underframe



Figs. 659 and 660.—Elevation and Plan of Pipe Car.

B is formed of two down-swept members bolted in front to bearer plates on the front cross-pieces of the frame A, and bearing upon a second cross piece to the rear. The flywheel clutch G drives the gear in box H. There are four forward speeds and a reverse, and the usual direct through drive on the top speed. The countershaft J, with differential, transmits the drive through sprockets

L to side chains, and carries a band brake, M, applied by pedal N. The driving wheel band brakes O are applied by the side lever P. The carburetter is gravity fed from petrol tank Q, under the seat. The steering gear is as usual, R being the hand wheel, and there being an enclosed worm and wheel. T is the speed-change lever, and U the clutch pedal. The silencer V is alongside the water tank W, at the rear. The chassis is said to weigh 686 kg. (13·5 cwt.), and the car either 838 kg. or 889 kg. (16·5 or 17·5 cwt.). The Richard motors and change-speed gear are described on pp. 243 and 393 respectively.



Figs. 661 and 662.—Elevation and Plan of G. Richard 40-h.p. Car.

The Rochet-Schneider wood and flitch-plate frame A, Fig. 663, supports an angle steel underframe, B, which carries the 20-h.p. four-cylinder motor C (described on p. 243) and change-speed gear D. Behind the front honeycomb tank and radiator E is a belt-driven fan. The cone clutch F differs from the usual type in having the spring, that normally causes it to engage, stationary. In the change-speed gear the first-motion shaft is beneath the second-motion shaft, and from the sprockets on the differential countershaft the rear wheels are chain-driven. Two band brakes on the countershaft, one each side of the gear box, are applied simultaneously by a pedal. The side lever J operating the change-speed gear is mounted on a shaft passing right across the car; it is moved either forward or backward in one or two parallel slots in the sector H, and any of the four forward speeds can be obtained without passing through intermediate positions. Lever J also operates the reverse. The side band brakes operated by lever G are compensated by introducing small helical springs between the frame and the usual fixed portion of the bands. In the steering heads, the forked bearing, instead of being rigid with and fixed to the axle, forms a part of the stub axle upon which the road wheels revolve, and the centre pin about which the forked bearings turn is solid with the stationary part of the axle: that is, the positions of the steering head that usually are stationary here turn with the wheels, and *vice versâ*. A ratchet wheel with pawl replaces the sprag, as in the Delahaye and Gladiator cars. The artillery wheels are 90 cm. (35·4 in.) in diameter, the track is 135 cm. (53 in.), and the wheel-base is 235 cm. (92·5 in.).

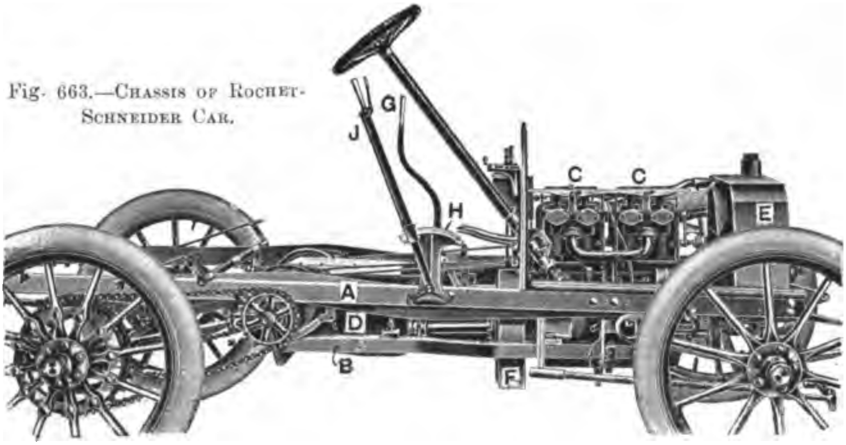


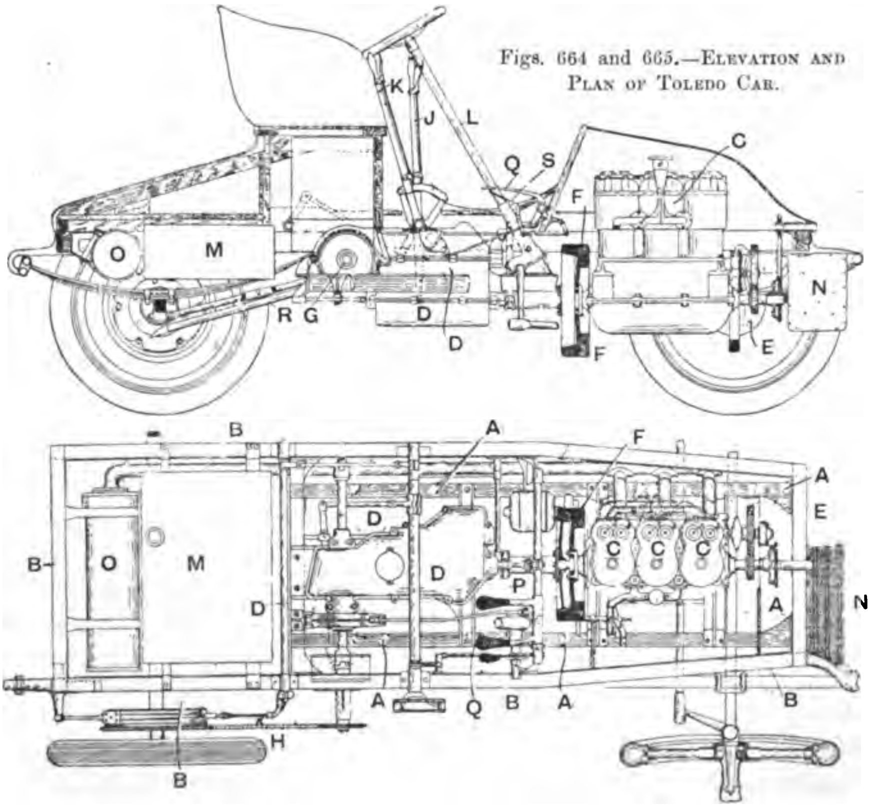
Fig. 663.—Chassis of Rochet-Schneider Car.

Star cars are representative of modern practice. They include a 6-h.p. voiturette, a 7 and 10-h.p. light car, all with twin-cylinder motors, and a 15-h.p. and a 20-h.p. car, both with four-cylinder motors. The 20-h.p. heavy car is here taken as a type. The four-cylinders have a bore and stroke of 108 mm. and 139·7 mm. (4·25 in. and 5·5 in.) respectively, and at 800 revolutions per minute 24-h.p. is developed on the brake. The crank-shaft is machined from a solid forging, and the crank chamber is of phosphor-bronze, the total weight of the motor being less than 250 kg. (5 cwt.). Both inlet and exhaust valves are 50·8 mm. (2 in.) in diameter, and all four valves can be got at by unscrewing two nuts, and the four-branch induction pipe containing the throttle valves can be removed by loosening two nuts which connect it to the induction pipe, the latter having a slotted flange. The valve cam shaft runs outside the crank case, the cams dipping into two cavities or drip chambers cast in the case and kept supplied with oil. A small glass lubricator oils the whole of the valve gear, and the rest of the motor is lubricated by a mechanical feed belt, driven from the crank-shaft, in the same lubricator being a paraffin pump for cylinder cleansing. Each pair of cylinders exhausts into a separate pipe to the silencer. The frame is of ash, armoured inside, and bolted together with steel angle plates. The channel steel underframe supports the motor and forward part of gear box. The four forward speeds and reverse are worked by a single lever, the change-speed gear being of the Panhard type. The clutch is of the self-centring type, the wheel-base is 229 cm. (7 ft. 6 in.), and the gauge 143·5 cm. (4 ft. 8·5 in.). All wheels are 86·4 cm. (34 in.) in diameter, and the tyres are 127 mm. (5 in.) in section ; the complete chassis weighs about 914 kg. (18 cwt.). There are the usual countershaft and side brakes, all of the band type and double acting. The tonneau body is of aluminium, and seats four people.

The Sunbeam 12-h.p. car has a main frame of ash and steel, an angle steel underframe carrying the four-cylinder motor and change-speed gear, both of which are encased in sheet metal on the underside ; normal speed of motor is 800 revolutions per minute, bore is 80·7 mm. (3·18 in.), and stroke is 118·8 mm. (4·68 in.). Inlet valves are atmospheric, and the throttle valve of the cylindrical plunger kind forms a part of the special carburetter. There are four separate exhaust pipes leading to the silencer alongside the motor, the gases afterwards passing through a pipe to the rear of the car. Transmission is by side chains, and the car is constructed on well-known lines. A matter of detail is that the two side levers have ball ends where they are gripped by the hands.

Many American petrol cars have all the features that British and Continental practice has developed.

The Toledo (American) petrol car (Figs. 664 and 665) is a modification of a European design. An angle steel underframe A, supported from the reinforced ash main frame B, carries the motor C and transmission gear D. The vertical three-cylinder motor is mounted longitudinally. E is the shaft and F the clutch. A countershaft G driven by the sliding spur wheel change-speed gear drives the road wheels by means of side chains H. The three forward speeds and the reverse are operated by the inner of the two side levers J; K is the brake lever. Brakes are as usual, and the steering gear is of the familiar inclined pillar and wheel type L. The water tank M is over the rear axle, the radiator N in front, and the muffler O in the rear.


Figs. 664 and 665.—Elevation and Plan of Toledo Car.

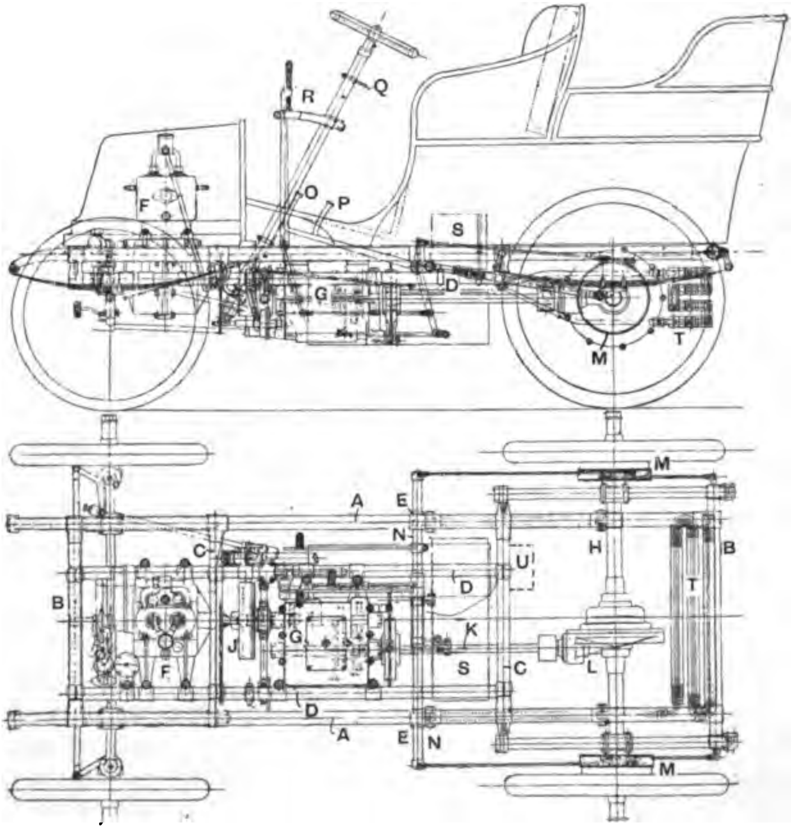
P is the clutch pedal, Q clutch and countershaft brake pedal, and R is the sprag. Working the brake lever K also withdraws the clutch. S, Fig. 664, is the throttle lever, shown also below Q in Fig. 665.

The Watsonia (Durkopp) cars, of German make, are in two sizes, one of them having a 10-h.p. two-cylinder motor and the other a 15-h.p. four-cylinder motor (*see* p. 250). The motor, with its internal flywheels, is in front, and the drive from the Panhard type gear is by side chains. Each half of the divided shaft connecting the differential gear to the side sprockets has a special brake drum, the band around which is applied by a steel cord passing round a pulley connected with the pedal, the result being that the effects of the two brakes are equalised. The usual side band brakes also are compensated. Motor and change-speed gear are carried on a separate underframe secured to the main frame, both frames being of channel steel and the main one being filled with wood.

Cars in which the drive is by means of a longitudinal shaft and bevel gearing to a live rear axle will now be described.

Ariel cars are of 10 and 16-h.p., the former having a two-cylinder and the latter a four-cylinder motor. In both cars the leading features are the construction of the light tubular frame with the brackets for carrying the mechanism, the accessibility and facility of removing the motor and gear box, the employment of a high-speed well-balanced motor, and the reduction of frictional losses in the transmission gear. In the 10-h.p. car (Figs. 666 and 667), the main frame A is suspended on semi-elliptic springs and has swinging distance rods between it and the rear axle; it has four cross tubes B C, and all the frame is in the same horizontal plane. Two lower longitudinal tubes D are secured by drop brackets to the front and intermediate cross tubes. The brackets to which the suspension springs are attached, and those (E) carrying the rocking shaft which connects the hand lever with the side brakes, are built into the frame itself. To the lower tubes D are clipped the motor F and the change-speed gear G. The complete frame, which weighs about 54 kg. (119 lbs.), has a neat appearance, and provides the important bearings for the operating devices; like all such frames it lends itself to the attachment of parts without its being necessary to drill holes in it. The brackets E are shaped to receive the upper ends of the distance rods which connect the main frame with the rear axle H. The motor drives the change-speed gear through clutch J, and the final drive is by longitudinal shaft

K and the bevel gearing L. The side double-acting band brakes M are of a special form, the drums themselves being bolted to the wheels, and the weight of the bands being normally taken off them. The levers operating them pass from the ends of a traverse shaft N carried in brackets E, and a hand lever, not illustrated, projects upwards from the right-hand end of the shaft, which also serves as a fulcrum for the pedals O P and for part of the system of levers connecting the change-speed lever with the gear. A small hand lever Q on the steering pillar, connected with the contact breaker on the cam shaft, regulates the time of ignition, and a gradometer fixed to the quadrant R on the steering pillar indicates to the driver the gradient of the road upon



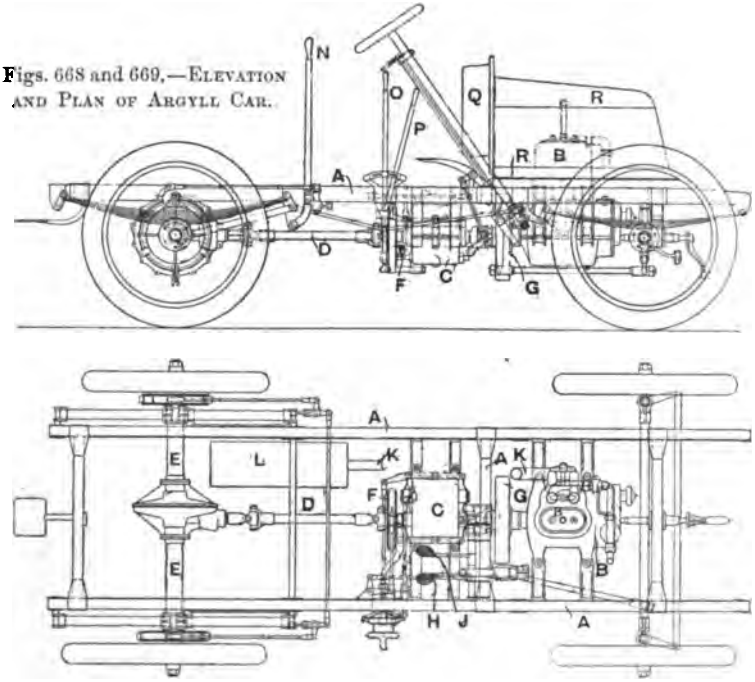
Figs. 666 and 667.—Elevation and Plan of Ariel Car.

which the car is travelling. The steering gear is dealt with on p. 447. The petrol tank usually is fitted in the back of the seat or in some other convenient position on the body, the water tank is beneath the seat at S, and the radiator T is at the back. The exhaust box is indicated at U. The wheel base is 198 cm. (6 ft. 6 in.) when the three-speed gear is fitted, and 213 cm. (7 ft.) with a four-speed gear. All four wheels are of the same diameter.

The Ariel carburetter is of the ordinary float-feed type, but long and careful experimenting have given something approaching perfection to the device. The air supply is taken through one of two passages, the more direct bringing the cold air and the other, running near the exhaust pipes, bringing the hot. By having the former adjustable, the temperature of the air supply can be regulated. For use at the highest speed, there is an extra air supply pipe with its inlet at the dashboard, its end being closed normally by a shutter under the control of the driver.

In the Ariel 16-h.p. car the motor is built up of two pairs of cylinders mounted in a similar manner on a differently constructed crank chamber. The crank chamber is made in two parts, an upper and a lower, the joint between them being horizontal through the bearings of the crank-shaft and sloping upward so as to divide the bearings of the cam shaft. A central crank-shaft bearing is, of course, provided. The crank-shaft itself is a solid forging and the flywheel is external. The drop-forged connecting rods have divided brasses at the big ends and are neatly designed. The motor weighs about 124·3 kg. (274 lbs.), and has proved itself capable of running up to a speed of more than 3,000 revolutions a minute, although its normal speed is 1,800. Six bolts hold it to the tubular main frame. The wheel-base is 231 cm. (7 ft. 7 in.). The petrol tank and water tank are somewhat differently placed. Two exhaust pipes lead from cylinders Nos. 1 and 3 and from Nos. 2 and 4 respectively to separate exhaust boxes, and the gases from the two boxes are then conducted to another box. The radiator is placed in front and consists of flat parallel tubes arranged in a frame with corrugated strips of metal between them: one set of tubes is horizontal and another set vertical, the one behind the other with a space between them. The starting handle passes through the radiator. A similar radiator, but having only one layer of tubes, is also fitted on some of the 10-h.p. cars, instead of the cooler at the back.

The Argyll 10-h.p. live rear axle car is constructed on well-known lines, Figs. 668 and 669 being elevation and plan of the chassis. The frame A is of ash, strengthened with steel plates, the motor B has two cylinders, the gearing C gives three forward speeds and a reverse, there being a direct through drive on the top speed, and the transmission is by longitudinal driving shaft, D, and bevel gearing to the live rear axle E. On the driving shaft is a brake, F, operated in conjunction with the flywheel clutch G by pedal H; the clutch is alone controlled by pedal J. The exhaust pipe and the silencer at the side are shown at K L the side brake lever at N, the forward speed-changing lever at O, the reverse lever at P, the petrol tank at Q, and the combined radiator and water tank at R. The heat is radiated by wire coils around the vertical tubes connecting the top and bottom tanks, circulation being natural. Other features are of a familiar nature.



Figs. 668 and 669.—Elevation and Plan of Argyll Car.

The modern Benz-Parsifal car is an entirely different vehicle to the old and well-known Benz car with horizontal motor. The modern car conforms in its general features to what is now more or less the general practice. The twin-cylinder vertical motor is described on p. 236, and the Richard-Benz carburetter is noted on p. 136. The main frame shown in the view of the chassis, Fig. 670, is of wood strengthened with flitch plates, and the motor and gear box (*see* Fig. 394, p. 393) are carried on an underframe, and the transmission is by a universally jointed shaft to a live rear axle. The radiator forming the front of the bonnet is composed of two frames, one in front of the other, built up with flat tubes with corrugated strips of metal between them. The main clutch is of the internal cone type, and is formed in the big flywheel, and the gear gives a direct through-drive on the top (third) speed. One lever operates both forward and reverse. The foot brake is of the internal type.

The Belsize 12-h.p. car has a two-cylinder motor with atmospheric inlet valves, whose springs are exposed. The exhaust valves are operated by rods passing upward through the crank chamber to rocking levers of ingenious design. Four flywheels are enclosed in the crank chamber, and there is a middle bearing for the built-up crank-shaft. The electric wire terminals for the contact breaker are fitted with springs, and are hollowed out to receive forked contact pieces on the ends of the wires. The springs prevent the wires from being shaken loose and allow for vibration. The terminals are stationary and the current is conducted from them to the rocking commutator by means of contact rings. The normal speed of the motor is 1,000 revolutions per minute. The main frame is of channel steel. In front of the dash is a water tank, and the radiator tubes encircle the bonnet and pass along above the frame at each side of it. The main clutch is of the cone type with internal spring, the gear gives three forward speeds and a reverse all brought into play by one lever, and the power is transmitted by a longitudinal shaft and bevel gearing. The brakes are in the road wheel hubs. As regards suspension, the front ends of the rear springs are fixed to sleeves which are free to slide upon horizontal pins, whose two ends are fixed to the main frame. The springs are not clipped to the axles at their centres, a greater length of spring projecting forward than backward. The Belsize 20-h.p. car has a three-cylinder motor, and the longitudinal crank-shaft drives through a clutch the change-speed gear, in which a small bevel wheel on the rear end of the second-motion shaft meshes with a wheel on a short cross shaft from which the power is taken by a single chain to the differential gear on the live rear axle; both shaft and axle run in ball bearings. An aluminium-leather case encloses the chain, which is exceptionally large. The change-speed and brake levers are arranged near the steering pillar instead of outside. The car weighs 914 kg. (18 cwt.), and the track is 142 cm. (4 ft. 8 in.).

Clement standard cars are two-cylinder 9-h.p., or four-cylinder 12 or 16-h.p., and in all the transmission is by longitudinal shaft and bevel gearing to a live rear axle. The smallest car has a wood and flitch plate frame and three forward speeds, whilst the others have a frame of stamped steel and four forward speeds. There is a direct through drive on the top speed. The motors had a distinctive arrangement of the low-tension ignition; the vertical ignition plugs formed inspection covers above the inlet valves, and their rocking arms were operated direct from cams carried on a cam shaft driven by bevel gearing and revolving in bearings across the top of the cylinders. A timing gear advanced or retarded the cams relatively

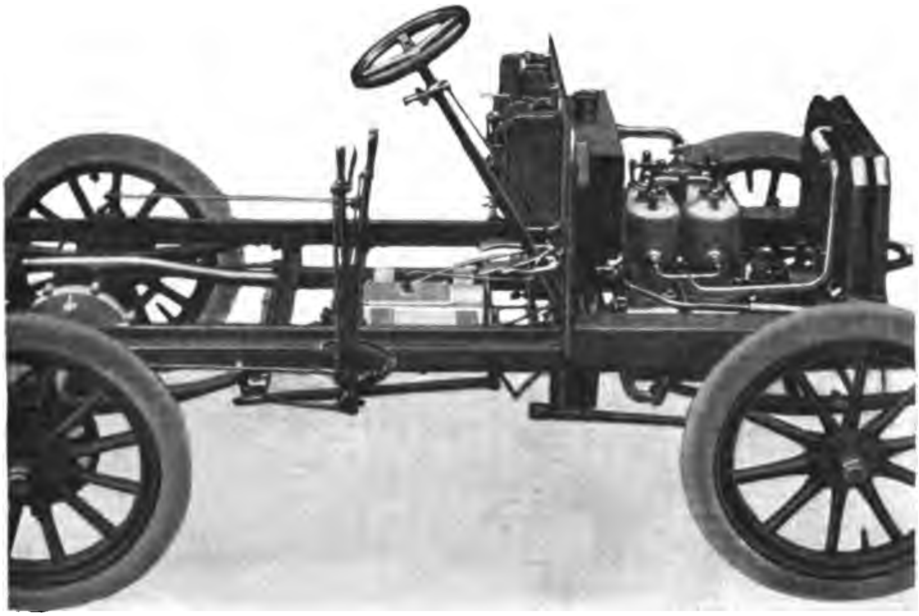


Fig. 670.—Chassis of Benz-Parsifal Car.

to the crank-shaft. Current was supplied by a gear-driven magneto or by a dynamo friction-driven from the flywheel. But this system has been discarded in favour of low-tension ignition. Inlet and exhaust cams are on one side of the cylinders, and are operated by a common cam shaft; a centrifugal force governor is enclosed in front of the crank chamber and operates a throttle valve. A single exhaust pipe passes across and connects the exhaust parts of all the cylinders, whether these number two or four. The Clement voiturette has a one-cylinder 6 brake-h.p. motor in front beneath a bonnet, and seats either two or three, there being a detachable back seat.

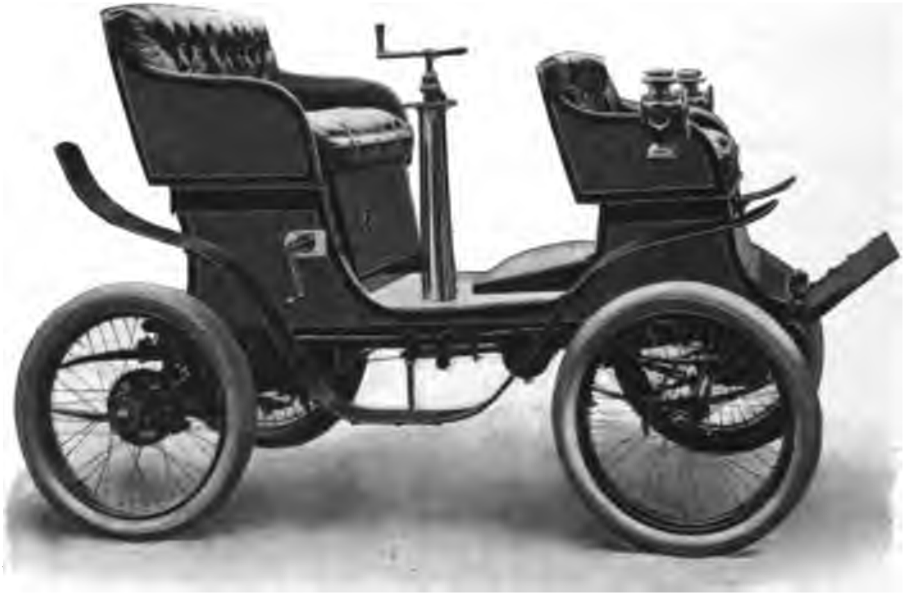


Fig. 671.—De Dion-Bouton Voiturette.

De Dion-Bouton voiturettes of the form illustrated by Fig. 671, with motor at rear driving a live axle (*see* Fig. 672), have become very familiar during the past few years, but now de Dion-Bouton models, whilst retaining some of the old features, more resemble other standard cars, and do not retain the outward design that has characterised the productions of the firm so long. There is still, however, the tubular frame and the live axle, but the transmission has been modified, and the change-speed gear is on a new design.

The de Dion-Bouton "Populaire" voiturette has a 6-h.p. single cylinder motor, A, in front (*see* the elevation and plan, Figs. 673 and 674). The motor has no external fly-wheel or clutch, the crank shaft being connected through a universally jointed longitudinal shaft, B, with the change-speed gear C, which is described in detail on pp. 400 to 403. The pump D for circulating the cooling water has its spindle coupled by a helical spring, E, to the motor shaft; the two shafts being in line a thoroughly flexible drive between motor and pump is secured. The change-speed gear is enclosed in a neat casing, C, rigidly fixed to the rear cross-members F G of the tubular frame. The gear box being rigid with the main frame, the drive is by bevel gear on to the differential gear, and thence by the well known de Dion-Bouton cardan axles to each of the rear wheels. The wheel bearings are connected together by a bent tube, H. The suspension springs J are semi-elliptic; the back ends of the rear ones are connected with the tubular frame by leaf springs, K. The radiator L is carried low. The wheels, either cycle type or artillery, are 68·6 cm. (27 in.) in diameter, the pneumatic tyres are 76 mm. (3 in.) wide, the wheel-base is 170 cm. (5 ft. 7 in.), and the tread 117 cm.

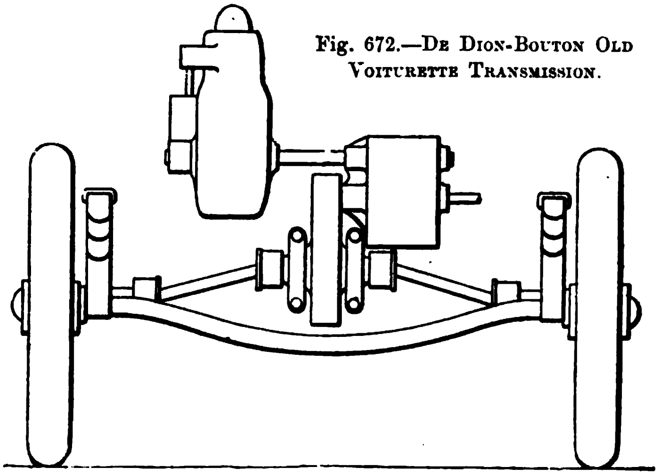


Fig. 672.—De Dion-Bouton Old Voiturette Transmission.

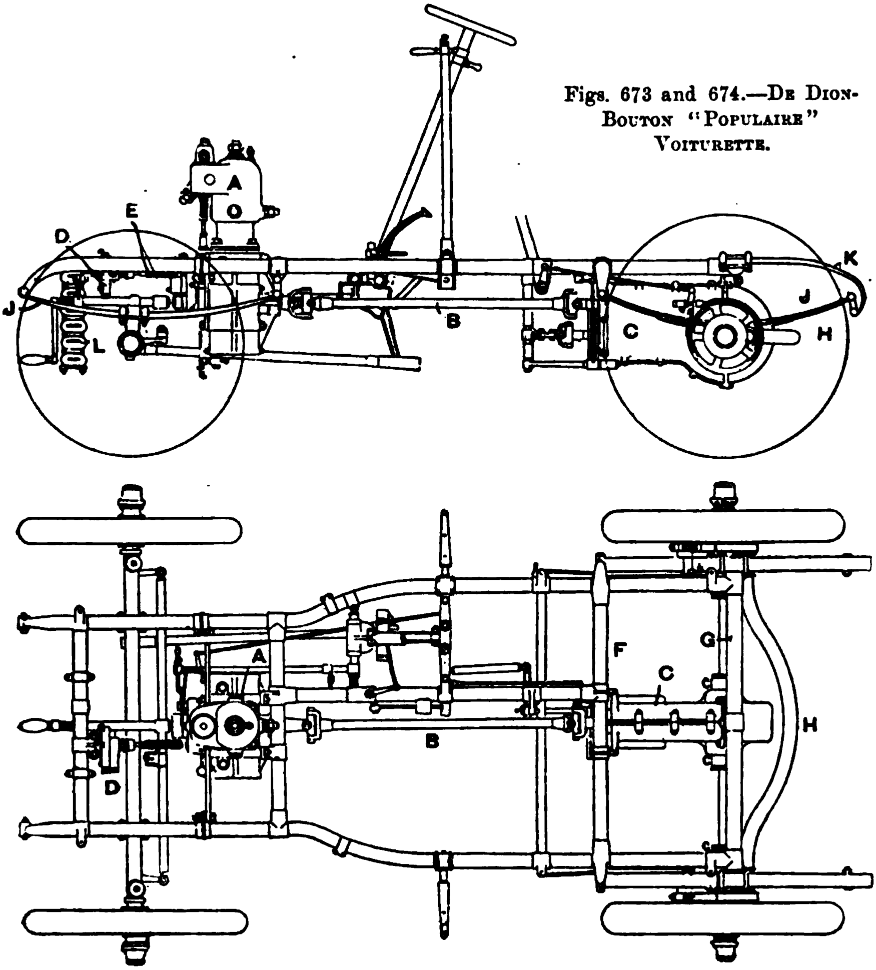
(3 ft. 10 in.). The standard body has a single seat for two persons. The weight with body is 1,370 kg. (27 cwt.), and the speed is anything up to 43·4 km. (27 miles) per hour.

The de Dion-Bouton 10-h.p. car has the two-cylinder motor described on p. 221, and the change-speed gear described on p. 403. The interesting system of suspension consists of semi-elliptic springs at the rear with their forward ends connected to the tubular main frame, and their other ends carried by an inverted transverse spring, whose centre is rigid with the frame. The forward ends of the front semi-elliptic springs are pivoted to a horn piece projecting forward and downward from the side members of the frame, whilst the back ends are held by swinging links to short curved leaf springs projecting forward and downward from the step bracket.

Darracq cars are of 8-h.p. one-cylinder, 12-h.p. two-cylinder, and 20-h.p. four-cylinder. The 12-h.p. car has a wooden main frame with steel flitch plates strengthened with corner pieces and an angle steel underframe carries the motor and change-speed gear. The general arrangement of this and of the 8-h.p. car is the same as in the 20-h.p. car, which has a stamped steel frame and underframe, the former having corner pieces, and the semi-elliptic suspension springs are long and nearly straight. The motor has mechanically operated inlet and exhaust valves, the former on the right and the latter on the left hand side of the cylinder heads. In the crank chamber are enclosed cam shafts, governor, and gear wheels, and beneath the front end of the crank-shaft is a water circulating pump driven by spur gearing. A cone friction clutch drives the change-speed gear, with which there is a direct through drive on the top speed, and thence the drive is through a longitudinal shaft and bevel gearing to the live rear axle. A powerful brake with metal blocks acting on a metal drum is fitted on the driving shaft immediately to the rear of the gear box. The rear axle, stiffened with underneath stays, is kept in position relatively to the change-speed gear by a tubular distance rod (this is employed also in the 12-h.p., but not in the 8-h.p. car). The radiator is multitubular, but in the other cars is of the flanged or gilled kind.

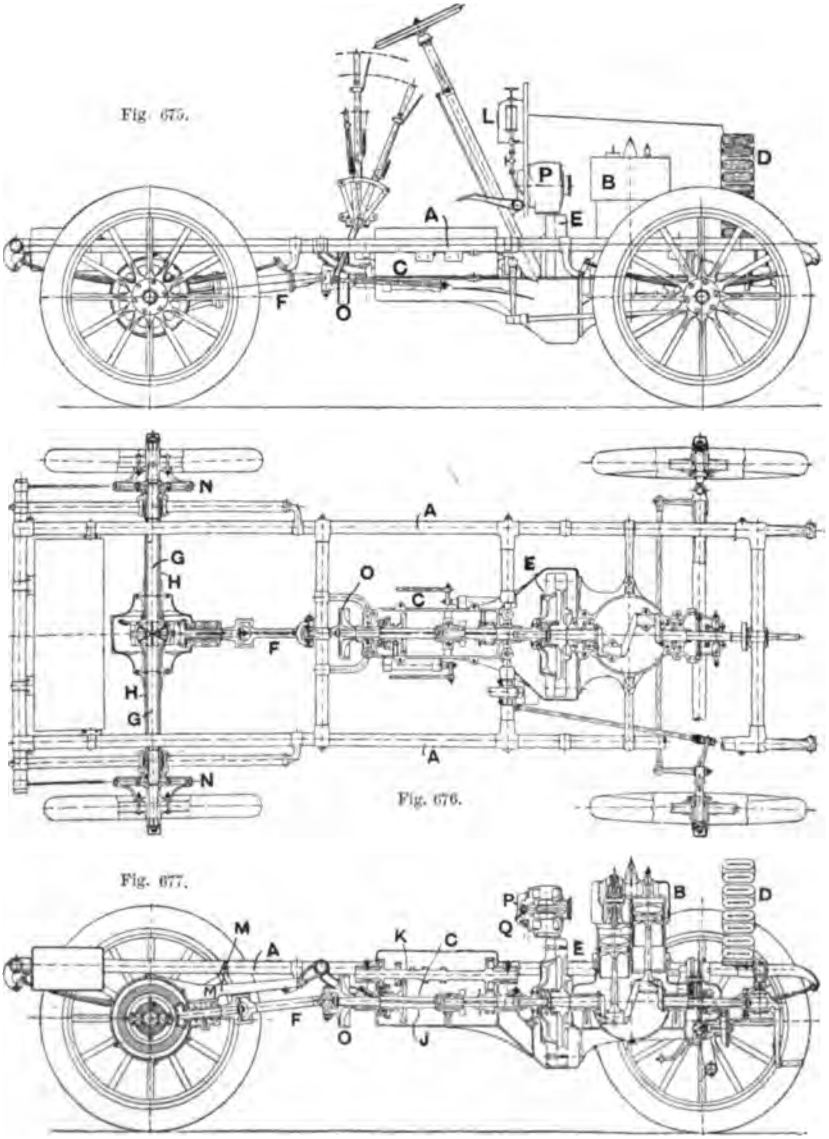
The Decauville nominal 10-h.p. car, as a specimen of engineering, is in the very front rank. Its design is on thoroughly good lines, and the whole construction is interesting. The chassis is shown on p. 631, in elevation by Fig. 675, in plan by Fig. 676, and in section by Fig. 677.

A stamped steel main frame, A, supports at a slightly lower level an underframe carrying the motor B, and change-speed gear C. The two-cylinder motor is described on p. 241; the base of its crank chamber is in one piece with the lower portion of the gear box. The Sthenos carburetter described on p. 121 is employed; the radiator D is of the Loyal type. The change-speed gear C is driven through the main clutch E, and a universally jointed longitudinal shaft, F, drives the live rear axle G H through bevel gearing. There are



Figs. 673 and 674.—De Dion-Bouton "Populaire" Voiturette.

four speeds and a reverse, and at the top speed there is a direct through-drive through shaft J; at other speeds a lay shaft, K, comes into use. In the Decauville four-cylinder 16-h.p. car the lay shaft revolves whenever the car is in motion, whether in use or not; in the 10-h.p. car it is inactive when not driving. In the gear-box casting are gutters for catching the oil thrown up by the gear wheels and for leading it to the bearings. Thus lubrication is automatic, without the necessity of leading pipes to the bearings from the dashboard lubricator L. In the design illustrated by Fig. 677 there is a distance piece, M, serving to strengthen the axle, between the latter and the main frame; but this has now been replaced by a strengthening tube around the longitudinal driving shaft, as shown at F, Fig. 675; tube and shaft thus form a strut. The bevel wheels connecting shaft F with the differential gear have ball thrust bearings, and the rear axle is a strong piece of work; the tubular portions H, connecting the differential gear with the road wheels, are machined up from solid forgings, and besides carrying the suspension springs which support the main frame, they, at their ends, form the bearings for the road wheels. The enclosed axle shafts G are turned up from solid forgings, and in the 16-h.p. car the jaw clutches on their outer ends are solid with them. These jaw clutches are arranged so conveniently that the rear wheels can be removed very quickly; the clutch is in the hub of the wheel, and forms the end of a shaft which can be drawn out bodily after removing the hub cap. Then the wheel is slid off. When replaced the jaw clutch shaft enters the boss of the differential gear-wheel which drives it, a square being formed on its inner end for the purpose. The side band brakes N in the 10-h.p. car are applied by a hand lever, whilst a band brake, O, on the differential shaft is applied by a pedal to the left of the driver. There is a special lever for putting in the fourth speed, another lever operating the three lower speeds and reverse. In the 16-h.p. car internal brakes operated by pedal and external brakes operated by hand lever are fitted to the rear wheel hub, and removal of the road wheels does not disturb them, and a single hand lever operates all speed changes. The dynamo P (*see* also Fig. 220, p. 241) and automatic cut-out are ingenious; the switch is operated by a centrifugal governor, Q, which completes the electrical circuit between the dynamo and the accumulators as soon as the motor speed is high enough for charging, and which severs the connection when the speed falls. The road wheels have pneumatic tyres whose outside diameter is about 80 cm. (31·5 in.). The



Figs. 675 to 677.—Elevation, Sectional Plan, and Sectional Elevation of Decauville Car.

extreme length and width of the car are 2·97 m. and 1·37 m. (9 ft. 9 in. and 4 ft. 6 in.) respectively. The 10-h.p. car has a top

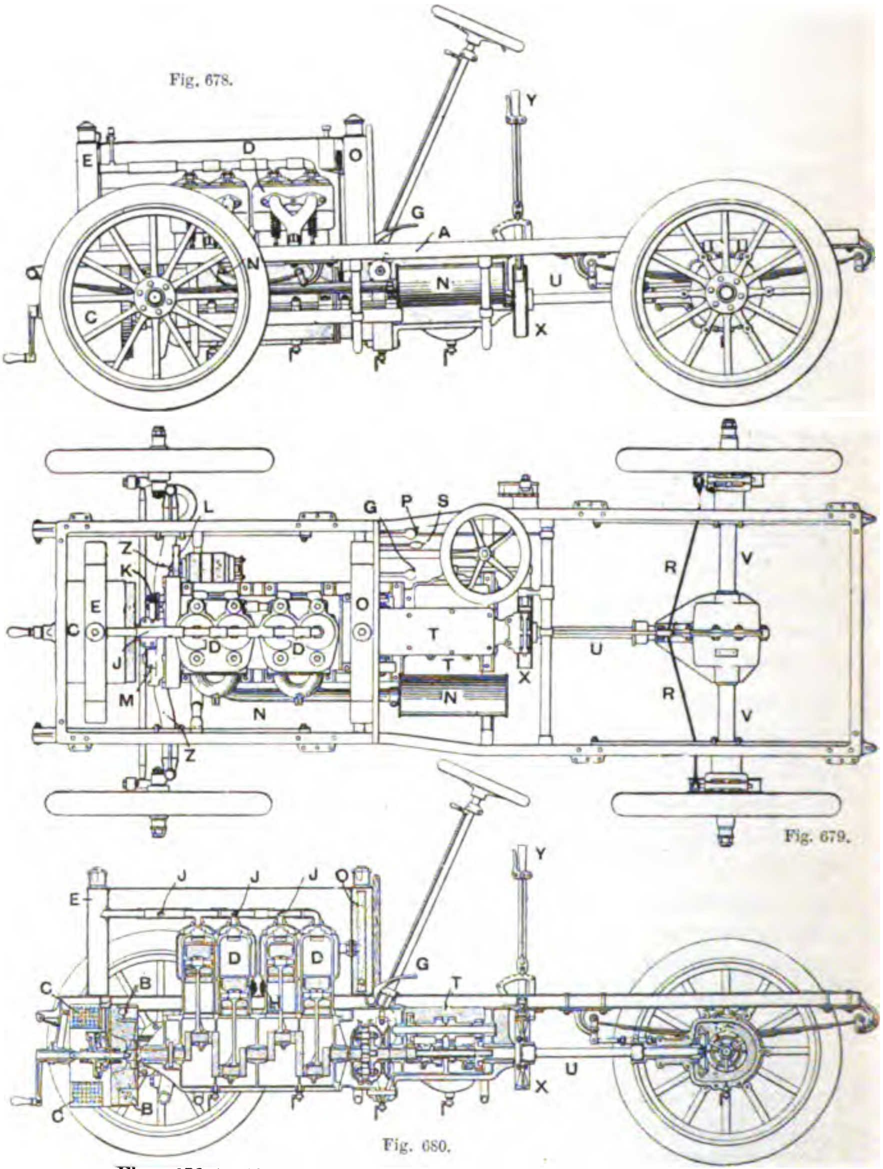


Fig. 678.

Fig. 679.

Fig. 680.

Figs. 678 to 680.—Elevation, Plan, and Sectional Elevation of Hautier Car.

speed of 60 km. (36 miles) per hour, and weighs empty 680 kg. (1,500 lb.), the loads on front and back axle respectively being 363 kg. and 318 kg. (800 lb. and 700.lb.). A petrol tank containing 34 l. (7·5 gal.) is carried.

Hautier modern cars are in three principal types, one, two, and four cylinder, and Figs. 678 to 681 are elevations and plan of the four-cylinder car. The motor is described on p. 247. The frame A and underframe are of channel steel, and the suspension is shown. The clutch, a special feature, is wholly metallic, and forms a variable transmission gear and speed reducer. The motor shaft driving the clutch revolves at, say, 1,000 revolutions per minute, but the change-speed gear shaft driven by the clutch revolves at only 200 revolutions. On the end of the motor shaft is keyed a pinion A, Figs. 682 and 683; the change-speed gear shaft ends in front with a double arm carrying two loose pinions, B and C, which gear with pinion, A, keyed on the motor shaft. The clutch shell D, running loose on the change-speed gear shaft, has an internal toothed ring whose teeth are always in gear with the two pinions B C. As the motor shaft rotates, the pinion A drives the two loose pinions B C carried by the transmission shaft, but this shaft itself is not moved because the pinions are loose upon it. The clutch shell D, itself loose, is driven by the two small pinions, but there is no transmission of power. If now the clutch shell is prevented from turning by being gripped between jaws, the two pinions B C can no longer rotate in one place, and so they are obliged to run round the stationary toothed ring, and to give motion to the change-speed gear

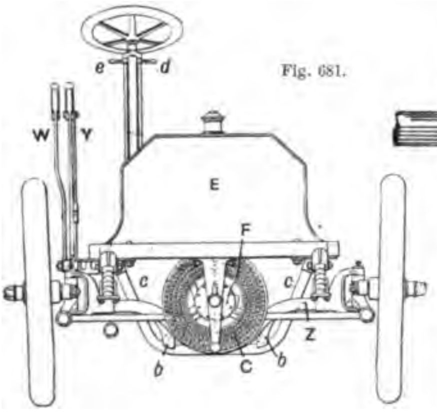


Fig. 681.

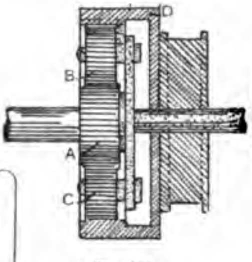


Fig. 682.

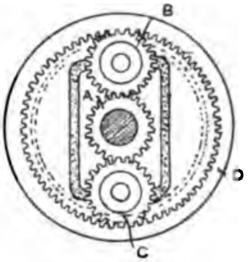


Fig. 683.

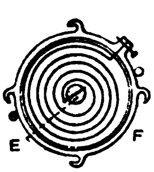
Fig. 681.—FRONT ELEVATION OF HAUTIER CAR.

Figs. 682 and 683.—HAUTIER CLUTCH AND SPEED REDUCER.

shaft on whose double arm they are carried. The relative diameters of the pinions and the internal toothed ring decide the proportionate speeds, and Hautier has chosen a speed reduction of five to one. To obtain progressive speed, the clutch shell is more or less gripped in the jaws so as to allow of slight slipping. In the 1903 type, the clutch shell has no longer a plain circumference, but has a coned friction surface, as have also the jaws A, Fig. 684. These jaws are bronze, and of the section indicated at B; they engage in the groove of the drum and gradually grip it, the action being similar to that of a band brake. The jaws are hinged at their base C; and through their upper part D passes a shaft, E, with right and left handed threads, a strong coiled spring, F (shown also in face view), constantly tending to turn shaft E in the direction to cause the screws to bring the jaws together and so hold the clutch shell stationary. The clutch pedal G actuates through rack H a pinion, J, keyed on the end of the shaft E, and this separates the jaws and releases the shell. The spring pressure is easily regulated by removing the box shown beneath the pedal G, Fig. 678. This clutch works smoothly and regularly, and constitutes the most distinguishing feature of the Hautier system.

Further details of the Hautier car may now be given: The flywheel B is forward of the motor, and acts as a ventilating fan to force a current of air through the radiator tubes C, Figs. 678 to 680. Its massive rim is pierced with six slanting channels, and it drives the air in a direction opposite to that in which the car travels, so as to produce a counterblast which causes an intense draught on the radiator tube flanges. Only 10 l. (2·2 gals.) of water need be carried for cooling the four cylinders D. The water reservoir E is in front above the radiator, and water descends into the centrifugal pump F, placed in the centre of the radiator. The pump shaft is also the actual motor starting shaft. The pump is of cast steel with bronze rings, and has long arms resting on the frame and supporting the radiator. The pump forces the water to the centre of the two groups of cylinders at H, and leaves the cylinders at the heads through metal pipes, which are joined by pieces of rubber, J, capable of resisting the highest temperatures likely to occur. Other details of the Hautier car will be largely apparent from the side elevation, Fig. 678; the plan, Fig. 679; the sectional elevation, Fig. 680, and the front elevation, Fig. 681, in which the letter references not yet explained are as follows: K, magneto driven by pinion L; M, motor governor; N, exhaust pipe and muffler;

O, petrol reservoir carburetter with filling plug; P, brake pedal operating the side band brakes through the cross rope R; S, accelerator pedal; G, clutch pedal; T, change-speed gear case with cover; U, longitudinal and universally jointed shaft driving the differential gear on the live rear axle V; W, hand lever operating band brake X on the driving shaft U; Y, change-speed lever; Z, front steering axle bowed downwards; *b*, motor supports; *c*, tubular cradle; *d*, mixture controlling handle; and *e*, spark advancing or retarding handle; both of these handles are mounted on the inclined steering column.



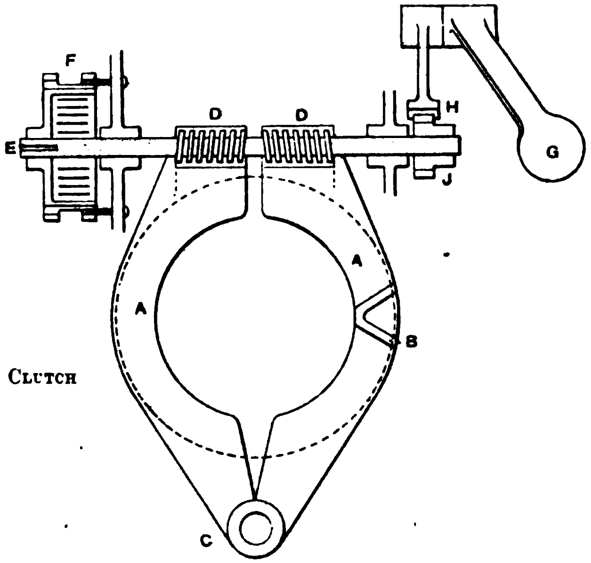


Fig. 684.—Hautier Clutch Jaws.

Eagle light cars with 8 or 9-h.p. single-cylinder motor or 12-h.p. two-cylinder motor have a tubular frame suspended above the axles by semi-elliptic springs, whose inner ends are carried upon the ends of inverted springs of a similar shape fixed centrally to the main frame, there thus being three springs beneath each side member of the frame. The motor is in front, and the transmission is by longitudinal shaft and live rear axle. The epicyclic change-speed gear gives two forward speeds and a reverse. Only one set of planet wheels gives the low forward speed and reverse, and the entire mechanism revolves as one piece in self-aligning spherical bearings on the top speed. There is a separate lever for forward speeds, reverse, and compensated band brakes on the rear wheels. Water circulation is natural, and the front multitubular radiator is somewhat on Mercedes lines. The steering arm has only one arm connecting the rim with the hub. A wick carburetter is employed, and the petrol tank forms the dashboard, being in the 9-h.p. car of 22·7 l. (5 gal.) capacity.

The Holcar 20-h.p. car is another radical departure; the four motor cylinders are separate castings, arranged in pairs, one pair being inclined to the other, an angle of 90° being formed between them. The two-throw crank has its crank pins at 180° from one another. A centrifugal force governor, mounted on a separate shaft, controls four interconnected throttle valves, one for each cylinder. A distinguishing feature of the car is the radiator, this consisting of a large number of small bore tubes forming the bottom of the bonnet, and also passing over it against the dash. The main clutch gives a double grip, and normally does not impose any end thrust on the moving parts; on putting it out of action, a brake in conjunction with it is applied automatically. A single lever operates the two forward speeds and reverse, and there is a direct through drive on the top speed, for which all the gear wheels are in mesh, there being no lay shaft. The drive from gear-box to live rear axle is through a universally jointed shaft, and there is a central radius rod. The steering pillar can be so moved that its angle with the main frame can be altered at will.

Horbick cars of 8-h.p. and 10-h.p. have tubular main frames and channel steel underframes, the latter carrying the two-cylinder motor and gear box. Transmission is by longitudinal shaft and bevel gearing to a live rear axle; and in the 10-h.p. car there is a spring cushion in the small part of the clutch, which is of the expanding type. The gear-box bearings have lubricators, chains replacing the ordinary rings. There is a neat telescopic coupling on the longitudinal driving shaft. The levers on the steering pillar regulating the mixture and ignition through Bowden wires, project from small friction discs, fitting against flat faces and pressed up against them by an adjustable nut. The wires leading to the ignition plugs are connected to spark gaps enclosed in a glass-fronted case on the dash, the current sparking across them on its way to the cylinders.

Humber cars are made in two sizes, 12 and 20-h.p.., and the resemblance between the two is great. The 20-h.p. chassis is shown by Fig. 685, and its tubular frame does not differ greatly from that shown by Figs. 522 and 523, p. 483. The change-speed gear box is supported by an inner and lower frame forming a cradle to which the box is attached by four nuts; on removing these the whole may be lowered to the ground without interfering with either gear or with the body. The front suspension spring is transversal, and the back semi-elliptic springs are at the side as usual; two horizontal tie-rods extend from the bottom of the cradle to the rear axle. The drive from the motor (*see* p. 230) is through an aluminium cone clutch and flexible shaft to the gear box (the change-speed gear is of the sliding spur wheel type), thence through a longitudinal shaft and bevel gearing to the differential of the live rear axle; the suspension springs here are relieved of twisting strains by an arrangement of tie-rods and guide box, whilst the thrust due to the bevel wheels is taken up by a ball race and an adjustable thrust bearing on the end of the driving shaft. Steering is by worm and segment. The radiator is either of the gilled type or honeycomb type, and in either case swings down whilst the bonnet swings up to allow of free access to the motor. The wheel base is 2·9 m. (9 ft. 6 in.), the track 129·5 cm. (4 ft 3 in.), and the weight about

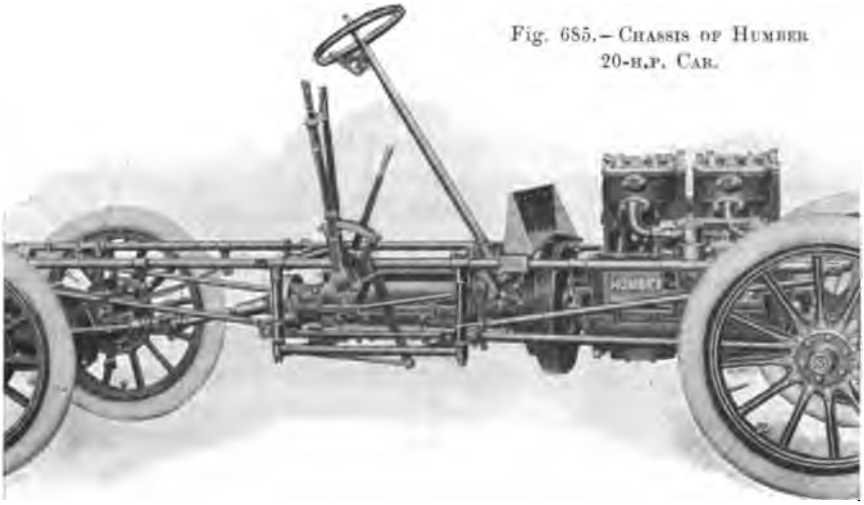


Fig. 685.—Chassis of Humber 20-h.p. Car.

1,070 kg. (21 cwt.). A description of the 12-h.p. car is unnecessary, as in all essential constructive details it is the same as the larger car.

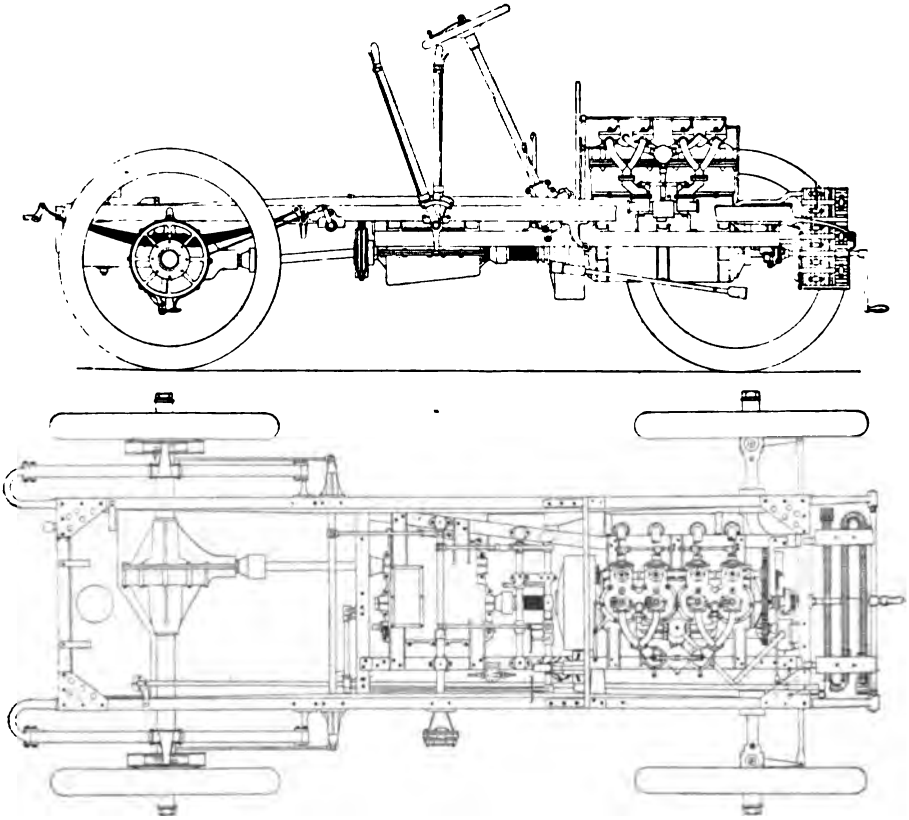
The Packard four-cylinder car (Figs. 686 and 687) more nearly conforms to European practice than does the car with one-cylinder motor as described on p. 673. It has a wood and steel frame, an underframe carrying the motor in front, a cone clutch with a usual form of drive, a gear box giving four forward speeds and a reverse, and a longitudinal driving shaft driving the live rear axle through bevel gearing. The carburetter has one float chamber, but it has two mixing chambers, one for each pair of cylinders. The motor cylinders, bore 101·6 mm. (4 in.), stroke 127 mm. (5 in.), and speed 1,000 revolutions per minute, are cast in pairs separately from their jackets, the four-throw crank-shaft is of nickel steel, ignition is by jump spark, current coming from accumulators, and a centrifugal governor controls both ignition and inlet throttle. A hand sector on the steering wheel operates an accelerator. Other features resemble European practice. The wheel-base is 2·34 m. (92 in.).

The Phœnix car is briefly noted on p. 600.

The Prosper Lambert light car or voiturette has a channel steel frame whose corners are strengthened with angle plates and projecting spring horns. A channel steel inner frame on the same level carries a 10-h.p. one-cylinder, vertical, water-jacketed motor with atmospheric inlet valves, and centrifugal force governor acting on the throttle. In the gear box, the first-motion shaft is just above the second-motion shaft, and the three forward speeds are operated by a single side lever, the reverse being brought in by a handle on the steering pillar. The main clutch drives through a flexible coupling the change-speed gear from which the live rear axle is driven by a universally jointed shaft. A metal-to-metal brake on the second-motion shaft is applied by a pedal, and internal compensated side brakes are applied by a side lever. The front axle is tubular. On the front of the dash is a water tank, and a positively driven pump circulates the water through a front radiator. A petrol tank is under the seat. The front wheels and live rear axle have ball bearings, and the standard vehicle has wire wheels.

The Renault 1903 standard cars are of 10 and 14-h.p. respectively. The former has a wheel-base of 201 cm. (79·1 in.), its wheels are 80 cm. (31·5 in.) in diameter, and it has 85 mm. (3·34 in.) tyres; the latter has a wheel-base of 202 cm. (79·5 in.), its wheels are 90 cm.

(35·4 in.) in diameter, and it has 90 mm. (3·54 in.) tyres. The following details, however, apply to both of the cars:—The frame is of 54 mm. (2·12 in.) diameter steel tubing, strengthened with truss rods, and an underframe carries the motor and gear box. The width over side tubes is 81 cm. (31·9 in.) and the wheel gauge is 102 cm. (40·1 in.). The 10-h.p. motor has two cylinders and the 14-h.p. motor four, and in each case the governor throttles the inlet, and ignition is high-tension electric, the plugs being mounted between the valve chambers and the cylinders, and the electrical connections being made to them by knife switches. The smaller motor has atmospheric inlet valves; the larger one has mechanically operated inlet



Figs. 686 and 687.—Elevation and Plan of Packard Car.

valves on the same side as the exhaust valves. Steel tie rods are fitted from the brackets which carry the rear ends of the front springs down through the step brackets, and up from there to the main frame above the rear axle. The main clutch, of the internal cone type, transmits motion to the change-speed gear, and thence a universally jointed longitudinal shaft takes the drive to the live rear axle. The change-speed gear with its operating mechanism is described in detail on p. 390. A forked distance rod, whose ends are connected to top and bottom of the differential gear casing, is pivoted at its other end by a ball-socket joint to a tube projecting downwards from the centre of the main frame. A pedal operates a steel-to-steel brake mounted inside the rear axle bevel-drive casing, and the side brakes are of the internal type and quite closed in.

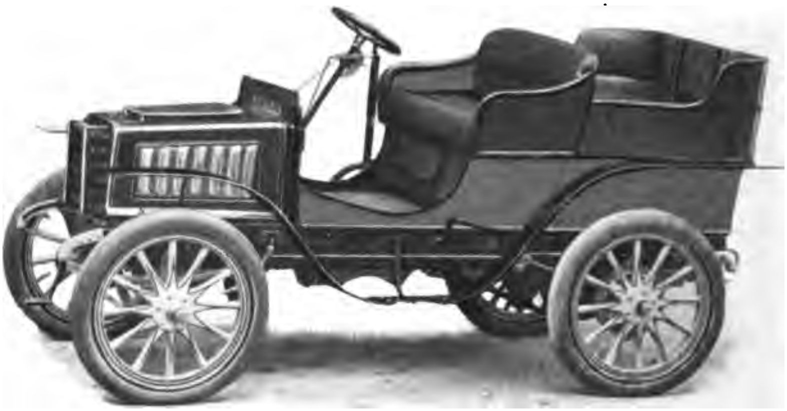


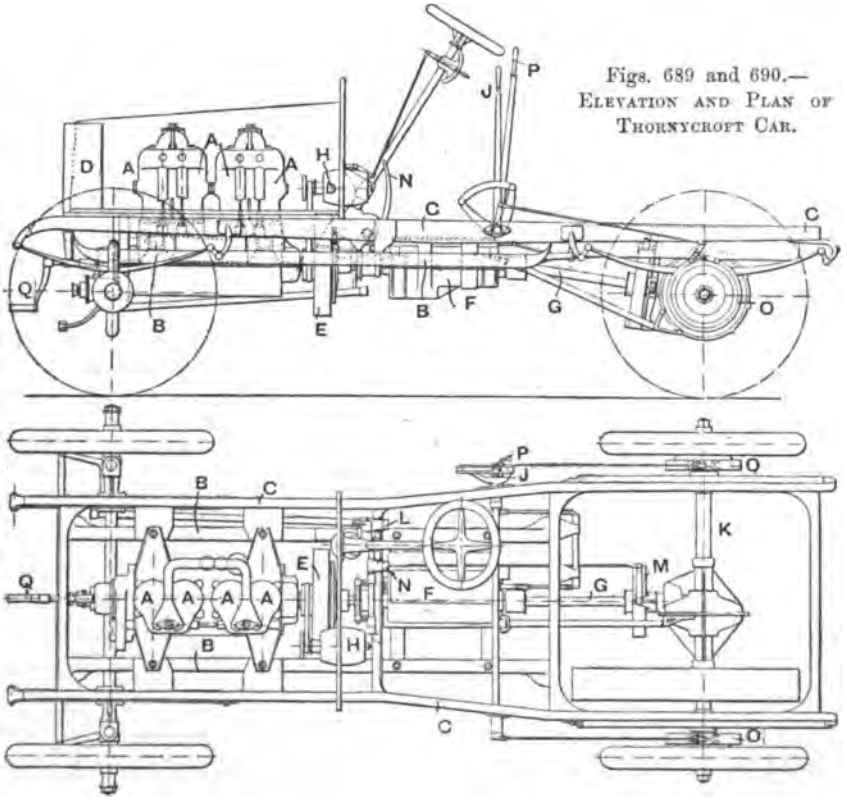
Fig. 688.—THORNYCROFT PETROL CAR.

Richard cars are described on p. 614.

The Ridley voiturette, with tubular frame and 4½-h.p. Buchet water-cooled motor, has two forward speeds, provided by bevel gears driving the live rear axle, the bevels having skew teeth, owing to the axis of those on the driving shaft being above the axis of the live axle. "Free-wheel" clutches replace the differential gear.

The Swift voiturette has a frame of tubular steel filled with ash, and rigid with the back axle, being carried in front upon semi-elliptic springs; it has four transverse tubes, to the two foremost of which is clipped the 4½-h.p. high-speed single cylinder motor, which is connected by a flexible coupling to a speed-reducing gear, whose casing is clipped to the third cross tube. The ingenious system of change-speed gear, arranged entirely round the live rear axle, is described in detail on p. 411. A differential is dispensed with, and instead there is a pawl-and-rachet device in the hub of each driving wheel.

Thornycroft petrol cars are particularly simple in construction. Fig. 688 is a photographic view of the 10-h.p. tonneau, whilst the line

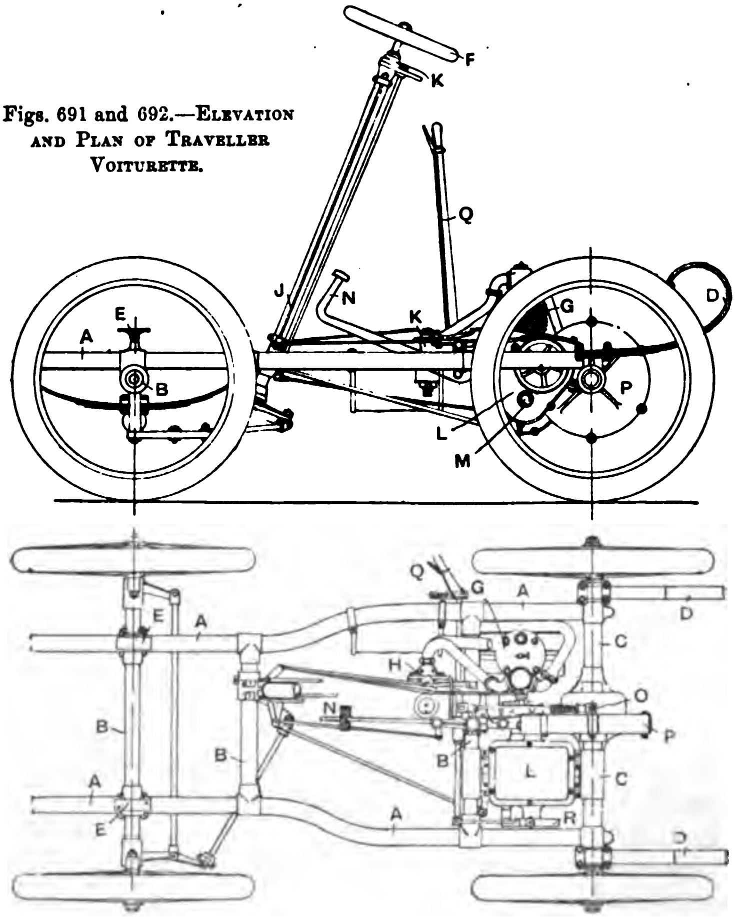


Figs. 689 and 690.—Elevation and Plan of Thornycroft Car.

drawings, Figs. 689 and 690, show the 20-h.p. car; the respective motors are described on p. 222, and the two cars are practically alike except in power and size. The motor A is carried on an underframe B suspended from the main frame C (both are of channel steel), in front being the radiator D and at back the flywheel clutch E, through which the motor drives the change-speed gearing F and rear road-wheels, the latter by means of a longitudinal shaft G and bevel gearing. Current for the high-tension ignition is supplied by accumulators or dynamo H;

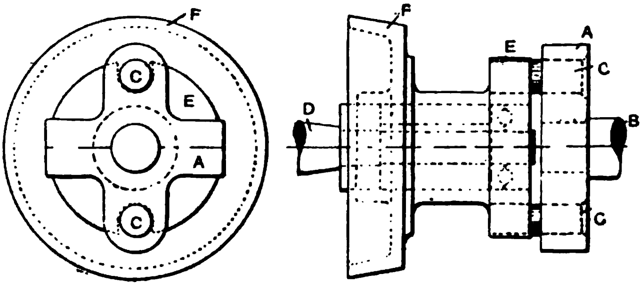
when a dynamo is used an accumulator is employed at starting and then is cut out automatically; to prevent the dynamo armature being driven at too great a speed, a centrifugal force governor on the dynamo spindle controls a friction clutch arranged between the spindle and the driven pulley, the dynamo being belt-driven from the crank-shaft. The main clutch E has two friction pads, leather or fibre covered, maintained in pressure contact with the flywheel by a powerful helical spring round the main driving shaft; the spring acts through a special balancing device which ensures that the friction pads are pressed outwards equally against the internal surface of the flywheel. The centrifugal tendency of the pads is compensated by a pair of adjusted weights, so that the clutch can be withdrawn by a light pressure of the foot on the pedal whatever the speed of the motor. The "striking bar" passes through the upper part of the aluminium gear box F; when placed near the bottom of the box, as in some cars, there is a leakage of lubricating oil. The three forward and one reverse speeds are operated by lever J, and there is a direct through drive on the top speed. The divided rear axle, encased in a tube K and carried in two phosphor-bronze bushes, is stiffened by a pair of steel stays connecting the base of the gearcase with the ends of the axle tubes, thus forming a deep truss and giving very strong construction, and the axle itself is relieved from all bending stress. Suspension springs are semi-elliptic and the artillery wheels have Clipper-Michelin tyres 80 cm. (31·5 in.) in diameter and 85 mm. (33·5 in.) wide. The clutch E is controlled by pedal L, and a double-acting band brake M on the longitudinal driving shaft is applied by pedal N. The side brakes O are applied by lever P. The starting handle is shown at Q. The 10-h.p. car weighs 660 kg. (13 cwt.) and the 20-h.p. car 762 kg. (15 cwt.)

The Traveller voiturette (Alldays & Onions) is shown in side elevation and plan by Figs. 691 and 692. The main frame A is weldless steel tube and has three transverse members B. These tubes are all in the same horizontal plane, and are connected together by brackets, as in cycle construction. The frame is carried at the rear upon the stationary tube C surrounding the live axle, and it is suspended above the front axle by semi-elliptic side springs; it carries all the driving mechanism, whilst the body is carried at the back by rearwardly projecting cee-springs D fixed to the main frame, and it is attached in front through brackets E pivoted to the tubes A. The body is, therefore, suspended on front and rear springs above the axles, although it is hinged direct to the frame in front. The steering gear, of the inclined pillar and wheel type, is rigid with the frame, and the steering wheel F has consequently a certain amount of movement relatively to the driver's seat; this feature is somewhat of a drawback to methods of suspension of this kind, but the resulting discomfort to the driver is only trifling, and the cost of construction is considerably reduced. The vertical single-cylinder high-speed motor G is fixed to the main frame under the driver's seat, its crankshaft projecting to the left; the bore is 85·7 mm. (3·375 in.) and the stroke is 82·5 mm. (3·25 in.). The cylinder wall has radiating ribs, whilst the head is water cooled. The atmo-



Figs. 691 and 692.—**Elevation and Plan of Traveller Voiturette.**

spheric inlet valve has a visible spring. The built-up crankshaft carries two flywheels enclosed in the crank chamber. The power is 4-h.p. at 1,500 revolutions a minute. The float-feed spray carburetter H has a throttle valve, worked by a lever mounted on steering pillar J. Two other levers are also fitted to the pillar, in addition to K, which controls the change-speed gear; one regulates ignition and the other controls the supply of auxiliary air to the working cylinder. The cooling water tanks form the sides of the body at the rear, and are cast with a ribbed external surface; circulation is on the thermo-syphon principle, no pumps being necessary since the tanks are at a higher level than the cylinder head. The sliding spur wheel change-speed gear L is encased. The motor is connected to the first motion shaft M through a flexible coupling formed by a flange on the latter carrying two projecting pins, which engage in corresponding slots in a flange fixed to the crank-shaft (see Figs. 693 and 694) in which A is the block or flange on the first-motion shaft B, C is the pins, D the crankshaft, E the disc containing the slots, and F the clutch). The gear-box L is in three pieces, and is secured to a cross-tube of the main frame and to the tube around the rear axle. The cone clutch between crankshaft and first motion shaft is operated by pedal N, which also applies band brake O around the differential gear. The power is transmitted from the change-speed gear to the rear live axle (carried in four ball bearings) by a pinion on the right-hand end of the second motion shaft engaging with a larger spur wheel surrounding the differential gearing. The two halves of the rear axle are enclosed in outer tubes C rigid with casing P surrounding the differential; a coil brake encircles its shell. The change-speed gear is operated by horizontal lever K carried



Figs. 693 and 694.—Traveller Flexible Coupling.

on the steering pillar. A side lever Q operates band brake R on the second motion shaft; this lever has a pawl which engages with a toothed rack and holds the lever in any desired position. The 9 l. (2 gal.) petrol tank is fixed behind the front seat, and beside it is 1·7 l. (3 pt.) lubricating oil tank. A grease cup on the second motion shaft between gear box and driving pinion contains solid lubricant which automatically feeds the shaft if this becomes heated. The road wheels are of the cycle type and have Clipper tyres. The body seats two at the back and one in the front. The speed may be anything between 4·8 and 38·6 km. (3 and 24 miles) an hour, and the weight is exceedingly low, between 254 and 279 kg. (5 and 5·5 cwt.).

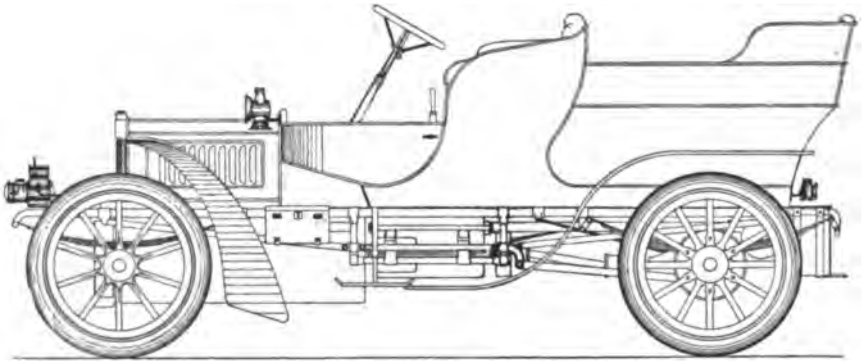


Fig. 695.—Elevation of Velox Car.

The Velox car is among the most advanced of British cars. The general appearance of the car is indicated by Fig. 695, and Fig. 696 gives a photographic view of the chassis. The tubular frame is stiffened with stays, and four brackets carry the motor, whose crank chamber has four feet which are bolted to the bracket. The gear box is supported by two longitudinal tubes, themselves carried by cross tubes; it can be bodily removed by taking off four nuts. Between the gearing and the motor clutch is a flexible coupling, this coupling (*see* p. 498) being a feature of this car. The frame is carried back and front on semi-elliptic springs, but the back ones are not pivoted direct to the frame; instead, guide forks solid with the spring plates which hold the springs to the axle, prevent the rear axle from moving in any but an up-and-down direction. The guide forks slide in square sockets rigid with the frame, thus providing a kind of horn plate.

Rubber blocks above the spring plate serve to cushion the blow in the event of the wheel rising more than a certain distance on an exceptionally bad road. Springs normally hold the distance rods in their proper position relatively to the axle, but allow the pin about which they are fitted to slide lengthwise if necessary; thus the distance rods are not pivoted direct to the axle. The longitudinal shaft which transmits the power from the spring-drive device outside the gear box (see p. 497) to the live axle bevel gearing allows for any relative movement between axle and frame. The distance rods curve outwardly towards the axle. The nominal 12-h.p. motor (16 brake-h.p. has four cylinders of 92 mm. (3·625 in.) bore and 101·6 mm. (4 in.) stroke, the speed being 900 revolutions per minute. Each pair of cylinders is a separate casting with the heads, valve chambers and jackets, the last-named having dome tops held down by a single bolt. The induction valves are atmospheric, the carburetter has the usual float feed, and the high tension ignition plugs fit into the side walls of the valve chamber between the inlet and exhaust valves. There is provision for auxiliary tube ignition. A centrifugal force governor in the cam shaft gear wheel operates two throttle valves; an accelerator operated by a lever may prevent the action of the governor, and speed may then rise to 1,500 revolutions per minute. The longitudinal driving shaft extending from the sliding spur wheel gear box to the live axle differential, carries a combined brake and spring cushion device which is described in detail on p. 497; there are the usual double-acting side brakes. The steering gear is described on p. 447, its point of interest being the capability of easily adjusting the angle of the pillar to suit the driver. The inner one of the levers shown in the view of the chassis (Fig. 696) operates the change-speed gear, and the outer one the side brakes; whilst the inner of the two pedals operates the friction clutch (contained in the flywheel), and the outer one the band-brake mounted on the transmission gear. The foot plates on the pedals can be adjusted to any angle that suits the driver; the plates are pivoted at the bottom to the pedal arm, and slotted quadrants project from their upper sides in such a manner that they can be rocked to the desired angle before being fixed in position by a bolt passing through the slot. A hand sector working in conjunction with a third pedal regulates the motor speed and the accelerator. There is a separate lever for ignition, a commutator chain-driven from the cam shaft is mounted on the dash, and the induction coil and lubricator are on the dashboard. An aluminium two-chamber exhaust box is fixed below the rear tube of the frame. A 27 l. (6 gall.) petrol tank holding sufficient for a 240 km. (150 mile) run is beneath the front seat. A radiator forms the front of the bonnet: it consists of two vertical rows of Clarkson tubes (steel tubes inside wire coils) held in a frame forming a water space top and bottom, the top one having a filling cap; behind it is a fan with wide blades driven off the front end of the crank-shaft. In addition, there is a ribbed and stayed copper water tank below the radiator, and through a hole in it passes the starting handle. The wheel base is 260 cm. (8 ft. 6 in.), the track 130 cm. (4 ft. 3 in.), the height from ground to main frame is 61 cm. 2 ft.), the clearance between mechanism and road is 23·3 cm. (9 in.), overall length, width and height without hood are 3·65 m., 145 cm., and 137 cm. (12 ft., 57 in., and 54 in.) respectively, and the weight is

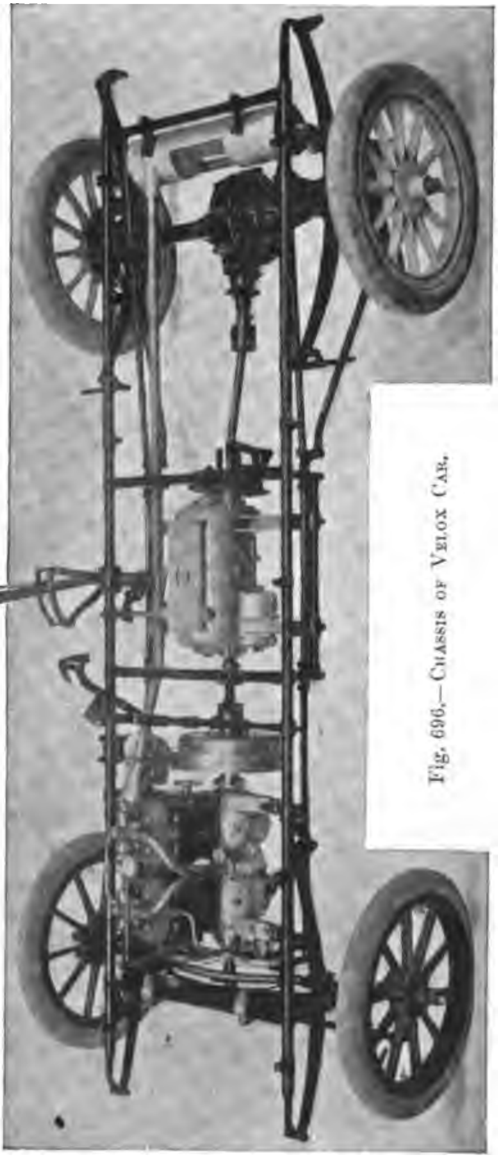


Fig. 696.—Chassis of Velox Car.

812 kg. (16 cwt.) The artillery wheels are 81·3 cm. (32 in.) in diameter, and have Dunlop tyres.

The Wartburg is a German car made in five sizes ranging from 5-h.p. two cylinder to a 22-h.p. four-cylinder. The smallest car has the motor at the back and a dummy bonnet in front: all the rest have the motor in front. The distinctive feature is the method of suspension. The tubular frame work carries the body in front by hinges on each side, and at the back by short semi-elliptic springs. There are no springs between the frame and rear axle, and the body is free to move on the front hinges. The front cross tube of the frame projects and terminates in vertical sockets forming the bearings for the steering heads of the front wheels. The sockets are free to slide up and down on the steering heads, at whose upper ends are thimbles, between which a leaf spring passes across the front of the car. The frame and the body are supported by this spring, and a swinging link passes downward from its centre to the front tube of the frame. The sockets in which the steering heads move take a bearing upon a slide inside the thimbles at the top of the heads, and they take any tendency which there may be for the front wheels to move over sideways.

Attention is now directed to cars with live axles and chain transmissions. The Belsize 20-h.p. car with such a system of transmission has been mentioned (*see* p. 624).

The Protos car has a very simple chain transmission from the change-speed gear (see p. 406) to a sprocket ring surrounding the differential on the live rear axle, as shown in the plan view of the chassis (Fig. 697). This is in the style of the light steam cars.

The Motobloc car is a radical departure, in which the chief object has been to condense the driving mechanism into as small a space as possible. The two cylinders of the 10-h.p. motor cast in one piece are bolted at an angle of about 45° to the crank chamber, which is in one piece with the gear box, and the cylinders project upwardly and forwardly beneath the dash. Both inlet and exhaust valves can be removed entirely, together with their seats. The normal speed is 1,000 revolutions per minute. Outside the large casing on the one side is the main clutch and on the other the flywheel, and the power is transmitted from the gear box (which gives three forward speeds and a reverse) by a single chain on the right-hand side near the main frame.

The Kitto 8-h.p. light car of American manufacture has a 38·1 mm.

(1·5 in.) angle iron frame, welded at the corners, carried upon elliptical springs. The live rear axle, driven by a single chain from the change-speed gear countershaft, has roller bearings, and both it and the front axle are tubular, and are stiffened with trusses. The 71·1 cm. (28 in.) wood wheels have pneumatic tyres. The motor has two vertical cylinders of 89 mm. (3·5 in.) bore and stroke, each cylinder being a separate casting with water-jacket and head. Ignition is high-tension electric, and the carburetter has a float-feed. A cone friction clutch connects the motor to the sliding spur-wheel change-speed gear, which gives three forward speeds and a reverse, the drive on the top speed being direct. Beneath the front hinged seat, copper tanks of 22·7 l. and 18 l. (5 and 4 gall.) capacity respectively hold the petrol and water.

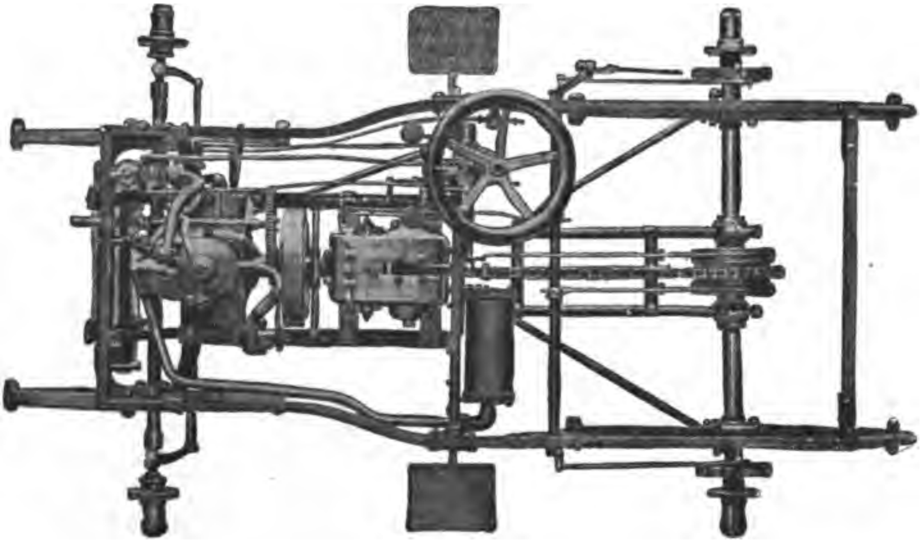


Fig. 697.—Plan of Chassis of Protos Car.

The Orient is a typical American light runabout car, weighing only 517 kg. (1,140 lb.). The wrought steel frame with the double supension carries the single-cylinder water-cooled motor of 4 or 8-h.p. The 8-h.p. motor is of 101·6 mm. (4 in.) bore, and 114·3 mm. (4·5 in.) stroke, the normal speed being between 1,200 and 1,500 revolutions per minute, the maximum being 2,400 ; its weight is 63·5 kg. (140 lb.). Tubular radius rods or braces connect the rear axle to the motor "hangers" in line with the shaft. The motor shaft carries the change-speed gear which is on the band brake principle, and gives two forward speeds and a reverse, the drive on the top speed being direct. Transmission is by chain from a sprocket on the motor shaft to a sprocket ring surrounding the live axle differential, which is of the planet wheel type. Circulation is effected by a pump, friction-driven from the motor flywheel. The overall length of the car is 2·8 m. (9 ft. 2 in.), the width 1·55 m. (5 ft. 1 in), the wheel base 2·03 m. (6 ft. 8 in.), and the tread 1·42 m. (4 ft. 8 in.), the wheel diameter being 76·2 cm. (30 in.) Fig. 698 shows an Orient production known as a buckboard.

The following cars belonging to the live axle, chain transmission type require more particular mention.

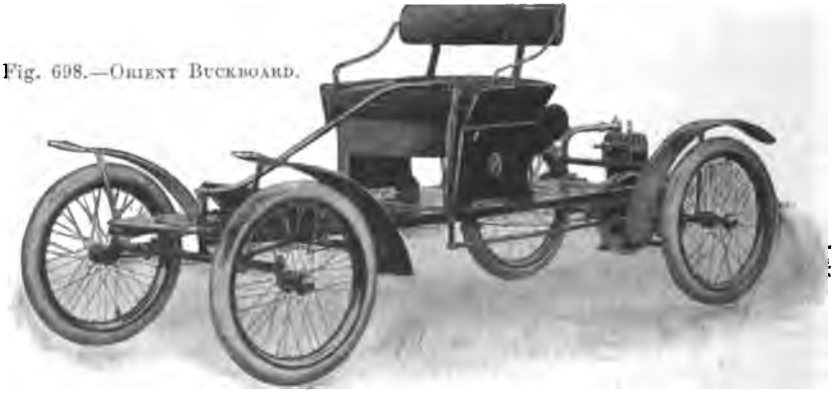


Fig. 698.—Orient Buckboard.

Cottereau cars are of 7-h.p., 10-h.p., and 16-h.p., the first two having the motor with two inclined cylinders, briefly described on p. 272, and the last-named having a four-cylinder vertical motor. A front view of the chassis of a 7-h.p. or 10-h.p. car is shown by Fig. 699, and the only difference between the two cars is the greater power and speed of the larger; the top speeds are respectively 42 km. and 48 km. (26 and 30 miles) an hour. The tubular frames have inner longitudinal members which carry the motor and gear-box. Three forward speeds and a reverse are provided, and there is the usual direct through drive on the top speed. Power is transmitted from the gear box to the live rear axle by a single chain driven by a small cross shaft which replaces the ordinary differential countershaft; the cross shaft carries at the other end to that on which is fixed the driving sprocket a band brake operated by a pedal, and a lever operates side band brakes. By moving the exhaust cams along the half-speed shaft, the motor can be made to act as a powerful brake when running down hills. The 16-h.p. car has a frame of wood and steel, a separate underframe carrying the four-cylinder vertical motor and Panhard type change-speed gear; there are four forward speeds and a reverse, the drive being direct on the top one, which is 65 km. (40 miles) per hour. Transmission is by side chains from a differential countershaft. The radiator is of the honeycomb type, and the circulating pump is gear-driven. The special lubricating system may be noted. On the dashboard is a neat grease feeder connected with the various bearings by six separate pipes, and having a handle turned right-handedly so as to screw down the plunger upon the grease; when this handle is turned left-handedly, instead of unscrewing the plunger it brings a small pointer opposite to indicating numbers, 1 to 6, on a dial, and when the pointer is brought opposite to the required number, a right-handed turn of the handle forces the lubrication down to that particular bearing.

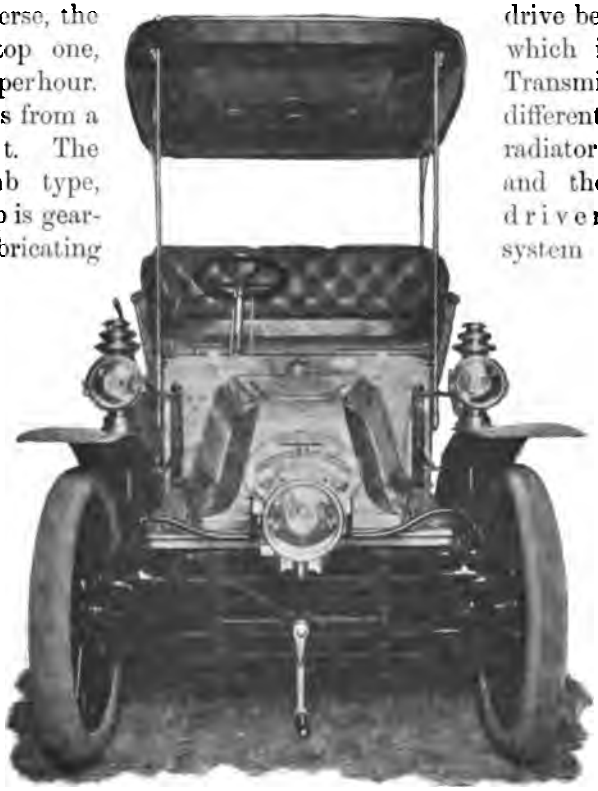
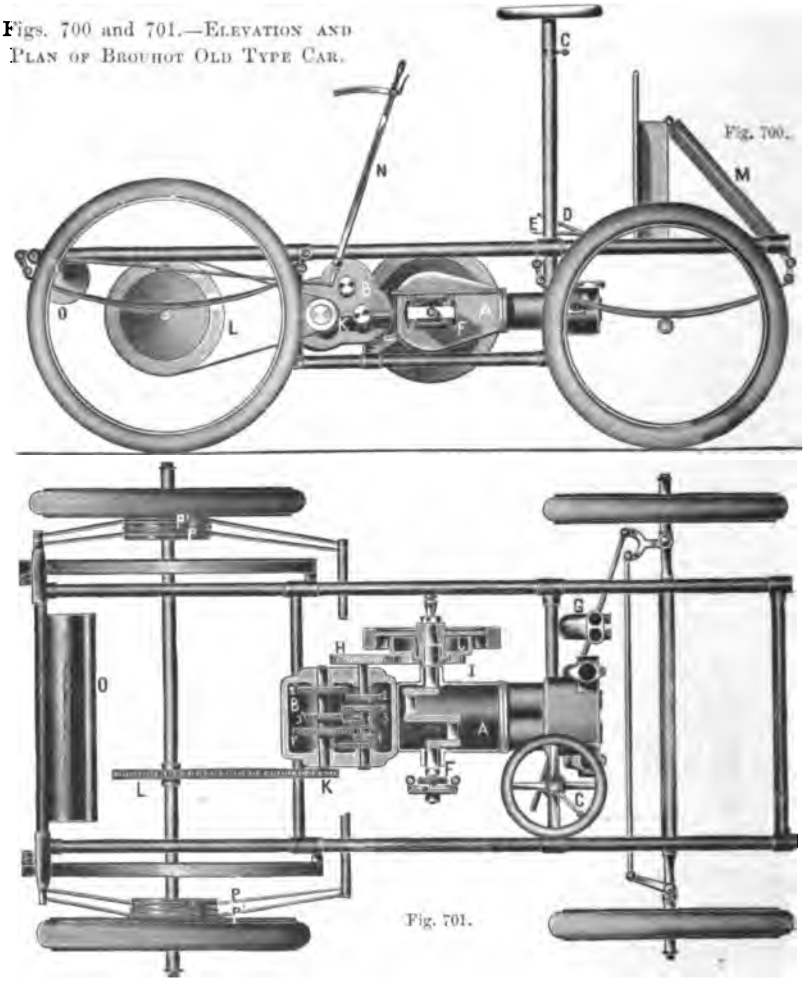


Fig. 699.—Front of Chassis of Cottereau 10-h.p. Car.

Though not in proper order, it is convenient to describe here three cars with horizontal motors.

The old Brouhot car had a horizontal motor of from 4 to 12-h.p. Transmission is by chain to a live rear axle, and there is no differential, a pawl and ratchet being employed instead.

Figs. 700 and 701.—Elevation and Plan of Brouhot Old Type Car.



An elevation of the frame, transmission mechanism, and steering gear of the Brouhot old type car is shown by Fig. 700, and a plan by Fig. 701. A is the motor, B the case containing the speed-changing gear, operated by lever C. Pedals D and E respectively operate the clutch and brake, F is the centrifugal governor, G the carburetter, and I is a pinion on the crank-shaft against the friction clutch J, meshing with a bronze toothed wheel H; the shaft of H passes through the change-speed gear box, and carries pinions gearing with toothed wheels on a second shaft ending with the sprocket K. This last drives sprocket L, which is mounted on the live rear axle. No differential gear is employed, this being replaced by a pawl device, illustrated by Figs. 702 to 704, in which *a* is the axle, *b* a ring toothed internally and keyed to the rear wheel, and *d* a pawl with three arms. One arm of the pawl engages in a slot cut into the axletree, and one of the other arms lies in one of the spaces between the teeth of the internally toothed ring. When travelling backwards the third arm of the pawl engages in the toothed ring, instead of the second one above mentioned. Thus the same effect as with an ordinary differential is obtained, whilst the rear axle can be made solid in one piece (*see also* p. 381). Returning to Figs. 700 and 701, O is the exhaust muffler, N is the brake lever, P and P¹ cord brakes acting directly on drums secured to the wheels, and M is the radiator.

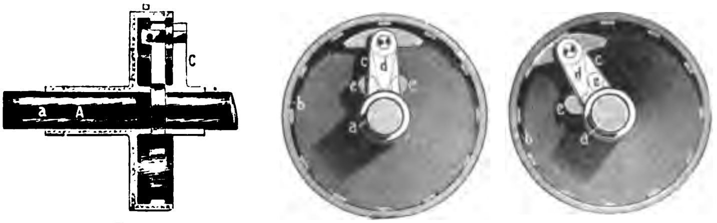
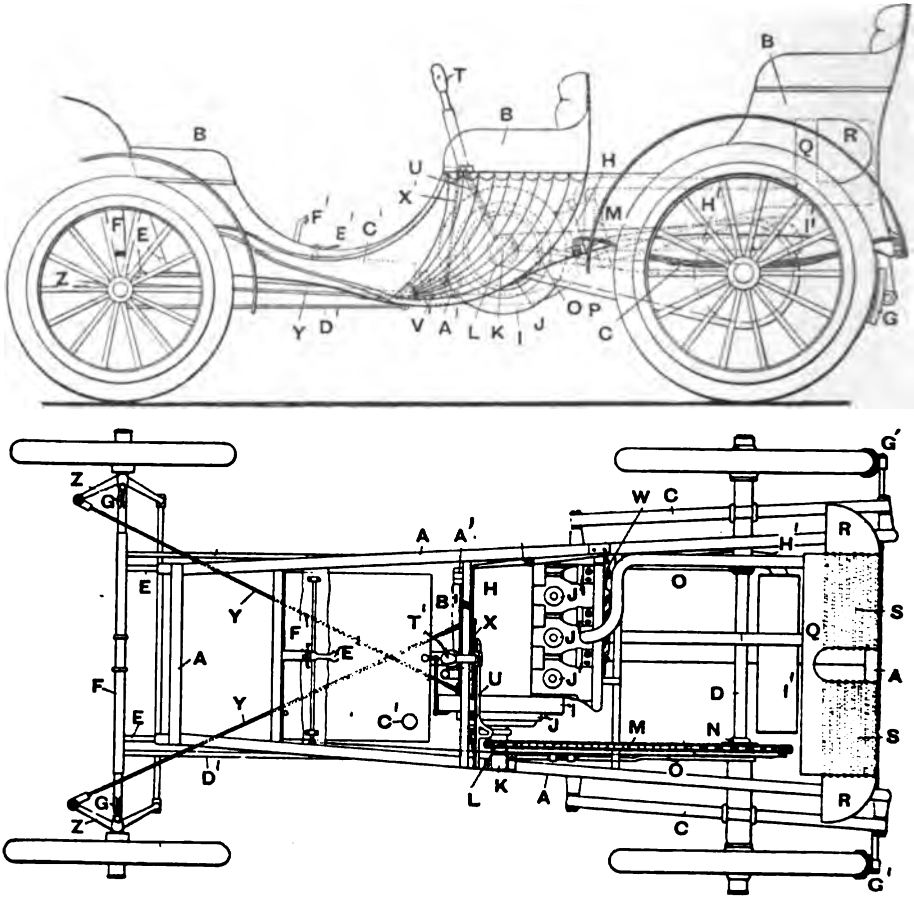


Fig. 702. Fig. 703. Fig. 704.

Figs. 702 to 704.—BROUHOT PAWL DEVICE.

The new Brouhot car is more of a conformation to standard practice: it has a vertical motor (*see* p. 248), and the system and the arrangement of parts are almost precisely as in other cars having countershafts and side chain transmissions. The countershaft now has a differential, and the pawl and ratchet device is not used.

The Duryea petrol car is an American production, designed on independent lines, and the side elevation and plan (Figs. 705 and 706) show that it differs from any other car on the market. It was introduced more than ten years ago, but since then has been greatly developed, the present system of construction having, however, been decided upon as far back as 1898, though the 1903 car, in the design of which Mr. H. Sturmey has collaborated with Mr. Charles E. Duryea, is a still more advanced type adapted to the requirements of the British and Colonial markets. The bent wood frame A has heavy strengthening irons and forms the frame of both car and body, B. At the rear it is carried upon the long springs C, resting upon a nickel-steel live axle D, and in front it terminates in dumb irons E, supported upon the ends of a transverse scroll spring, F, carried on the front axle G. The three-cylinder motor H has the flywheel I, and power drum J (described later) on the left-hand end of the crankshaft, which is supported in bearing K; a feature of the car is the direct



Figs. 705 and 706.—Elevation and Plan of Duryea Car.

drive by chain M, from the sprocket L to the differential N, on the axle D ; radius rods are shown at O, and the chain is enclosed in case P. Tank Q carries cooling water, and has ears and scoops, R, which force the air through the tubes S, and condense any steam that may be formed. The system of cooling is described on p. 197. The control of the car is practically vested in the handle T, which, by means of the clutch lever U, operates the clutches and changes the gear, and by means of the lever V actuates the throttle bar W, and controls the speed, and by means of the rocking lever X, chains X^1, and tension rod Y acts on the steering arms Z, and steers the car. The magneto is shown at A^1, the carburetter (*see* p. 134) at B^1, and the petrol tank at C^1 under the footboard. Stretcher bars D^1 hold the fore carriage and front axle square with the vehicle. The pedal E' operates an expanding brake inside the chain ring around the differential N, and pedal F^1, provided with a ratchet, actuates tyre brakes G^1 on the rear wheels. The exhaust pipe H^1 leads the gases to the silencer I^1. The general arrangement of the car having been indicated, some of the elements may be considered separately.

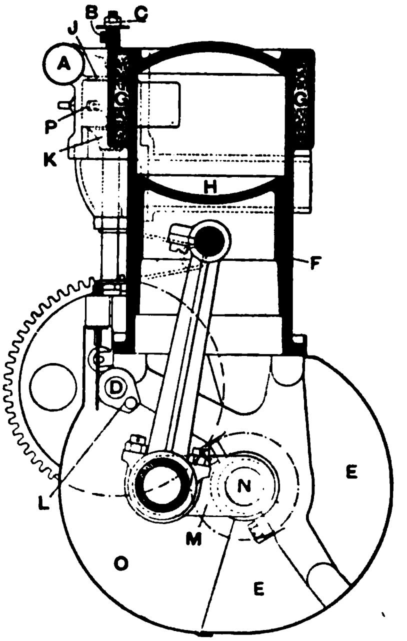


Fig. 707.—Vertical Section of Duryea Petrol Motor (shown on end.)

The Duryea horizontal motor has three cylinders, whose bore and piston stroke are 114·3 mm. (4·5 in.), and whose power is upwards of 10-h.p., the weight being about 90·7 kg. (200 lb.). In the cross section, Fig. 707, showing the motor on end, the induction pipe A leads across the head. A throttle slide, B, controls the lift of the inlet valves C, whilst D is the cam shaft, E the crank case, and F the cylinder. The one-piece cylinder casting has a water jacket, G, surrounding the heads, there being a single pipe connection to the water tank. Pistons H, inlet valves J, exhaust valves K, and cams L are interchangeable. The cranks M on shaft N are set at an angle of 120° with each other, the crank shaft N being in advance of the cylinder axis with the object of reducing shock and lessening vibration by giving a practically direct thrust; O is the crank case cover, and the cranks and cam shafts are lubricated on the splash system. (In Fig. 706, J^1 shows the oil cups). Ignition is by rotary magneto, which supplies current to three insulated "anvils" P. The ignition system is shown separately by Fig. 708. The shaft A of magneto B is driven by a small coned pulley, itself driven by the cone face of the big flywheel. A governor removes the pulley from the flywheel directly a safe speed is exceeded. The make-and-break spark is obtained as follows: Current from the magneto B is taken to coil C, and thence by a naked wire to the insulated "spark anvils" P in the cylinder heads, connections being made inside the cylinder by "spark hammers" D, passing through the hollow stems E of the exhaust valves. The trip levers F, at the base of the stems E, are acted upon by a lifting plate G, brought into action by contact with a roller, H, on the side of the same cam, J, which works the exhaust. The hammers are kept in contact with the insulated anvils until the trip lever drops off the lifting plate, when owing to spring K a very quick break is made and the spark produced. The battery L comes into use at starting, and it also acts as a standby; M shows the switch.

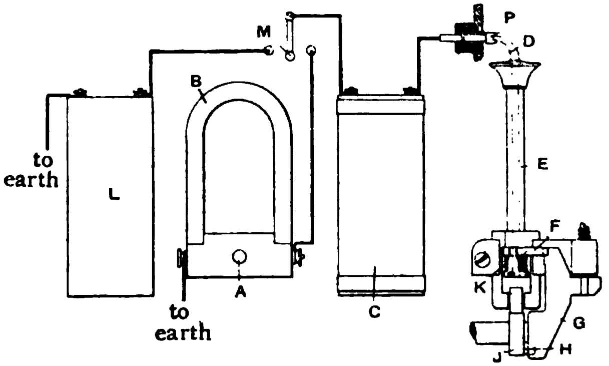
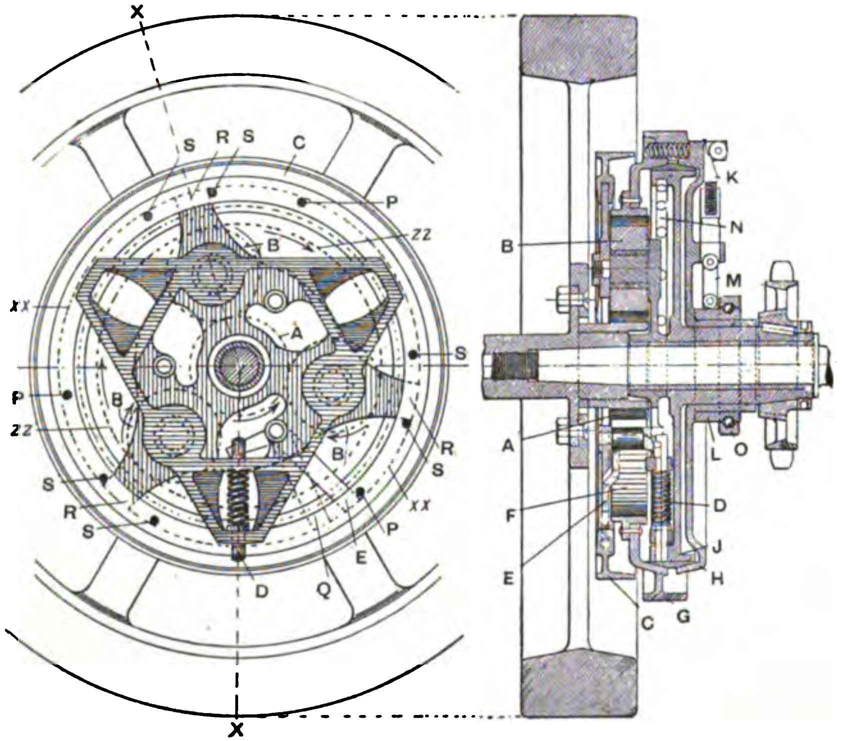


Fig. 708.—Duryea Ignition System.

Speed changing in the Duryea car is operated largely by merely throttling the motor, but ingenious gearing of the crypto-dynamic or epicyclic type is provided; this employs friction clutches of large surface which are contained in the "power drum" (J, Fig. 705) carried on the motor shaft and normally revolving with and locked to the flywheel, all teeth being in mesh but no gear working. Fig. 709 is a vertical section and Fig. 710 a front elevation of the speed-changing device, the following description of it being due to



Figs. 709 and 710.—Duryea Change-speed Gear.

Mr. J. E. Homens: The small gear A is secured to the motor shaft against the flywheel flange by screw threads. Meshing into the gear A are three idle planet gears, B, journalled upon studs provided on a triangular frame which is itself journalled upon an extension of the motor shaft; by this arrangement the planet gears are held concentric with the driving gear A, and both the gears and their supporting framework are further held in alignment with the various parts to which they may be attached in making the several changes. This triangular frame is double, one part being formed integral with the studs, and the other part attached to the studs by nuts on their projecting ends, which latter part carries the reverse ring C, while both parts of the frame form supports for the clutch pins D, and their actuating levers E (N shows groove containing perforations for admitting the pins D, when C and the slow speed ring G are locked together). Encircling the planet gears B is an internal gear F attached to the slow-speed ring G, which is supported upon the disc E by projecting lugs ; while the disc H in turn is journalled so as to remain concentric with the motor shaft and thus support the internal gear F in concentric relation and proper alignment with the other parts. Friction bands, not shown, are attached to the framework of the vehicle, and encircle the ring C and the ring G, being provided with levers by which either band may be caused to grip its corresponding ring at the will of the operator. If the reverse ring C is gripped by its band, the planet gear studs, with the attached framework, will be held stationary, and the motion of the motor will be transmitted from the gear A through the planet gears B to the external ring, which will be driven in a reverse direction. If the slow-speed band is gripped upon its ring G, the internal gear will be held in a fixed position, and the motion of the motor will cause the planet gears B to roll around inside the internal gear in the same direction as the gear A, carrying the studs of the planet gears B, with their framework, slowly in a forward direction, as will be explained later. If all parts are locked together in any convenient manner so as to prevent relative motion, they will then move with the motor and cause the driving sprocket to move at high speed forward, while if no clutch is in engagement the motion of the motor will turn the gears idly without producing motion of the sprocket.

More specifically these various motions in the Duryea device are accomplished as follows : The planet frame is normally held in engagement with the sprocket carrying disc J by means of the pins D, so that, holding the internal gear F by means of the slow-speed band, the other clutches being released, it carries the sprocket forward at slow speed. Since the planet gear frame and the disc J are normally in engagement, it is evident that clutching the ring F to the disc J will prevent relative motion of the planet gears and the internal gear, and thus cause the sprocket to be carried at the speed of the motor. This effect is produced by means of the conical friction surfaces on J, engaged by complementary surfaces inside the ring G and the disc H, which surfaces are brought in contact by means of the wedge K bearing against the disc H under the roller attached to the lug projecting from the ring G. This wedge K is operated by a shifting collar L and a toggle link M, a shifting lever, not shown, being attached to the outer ring of the ball bearing O. The section, Fig. 710, shows these surfaces in engagement; releasing is effected by moving the shifting collar L towards the sprocket, which withdraws the wedge K and permits the surfaces to be separated by the spring shown. The large surfaces and the toggle and wedge for closing them secure a very powerful pressure with little shifting effort, while the disc J is ordinarily surfaced with brass, which, having a higher coefficient of expansion than the cast iron against which it bears, is rapidly heated in case of slipping, and becomes self-tightening by expansion. Releasing all the clutches allows the sprocket with its disc J and the planet gear frame to stand idle while the internal gear revolves freely in a reverse direction, although the motor may be running.

Reverse motion in the Duryea car is secured by holding the ring C, which is mounted on the arms of the planet gear frame in such a manner that three sliding pieces, or plungers, normally projecting slightly above the outer surface of C, are pressed in by the gripping band; this motion moves three levers and withdraws the pins D from engagement with the sprocket disc J, thus separating the planet gear from the disc J. Since the band prevents further movement of the planet gear frame, while the disc J is free to move in any direction, owing to the withdrawal of the pins D, it is evident that the motion of the motor will drive the internal gear F in the reverse direction, and that clutching the gear F to the sprocket disc J by means of the high-speed clutch will cause the sprocket to be carried in the reverse direction along with the gear F. It is further evident that releasing the high-speed clutch will stop the reverse movement of the sprocket, while releasing the reverse ring C will permit the pins P to resume their normal position under the action of their springs. In Fig. 709, P shows the position of lever when pins D are inserted in holes N in J; and Q shows the position of the lever when the pins are raised from the holes. The spider arms R carry the three idle pinions B, and slide in a groove on C to the pins S. *X X* shows the line of the slot groove on C, and *Z Z* the pitch line of the internal gear on G. The whole device is quite compact, and the power is transmitted from the driving gear A to the various clutch surfaces in approximately a single plane, which lessen the torsion strains on the various parts and gives great strength with little weight of material. The driving sprocket is the outermost portion of the gear.

The Duryea steering system, entirely under the control of lever T, Fig. 705, has points of interest. With the object of absorbing at the wheel tyres the shocks caused by road inequalities, stones, etc., the steering heads have not vertically set centres; but are inclined sideways so that the line drawn through the centre of rotation meets the ground at a point just inside the point at which the vertical line drawn through the centre of the wheel meets it; this is just sufficient to give a slight lifting action. The wheel rotates upon its own centre, and not around its pivot; whilst by throwing the centre line a little inside the true point of incidence the slight lifting action is obtained when the wheel is turned, the weight upon it immediately tending to force the wheel back to its true path. This system is so effectual in absorbing the shock before this reaches the steering mechanism that there is no inconvenience to the hand when running over the roughest ground, and the car proves to be practically self-steering.

Fig. 711 shows the central vertical lever A, pivoted at B to the front of the seat, and carrying at its base a cross arm C, from which chains, D, pass round pulleys which are set at an angle under the car; the chains are connected to the steering arms by light tension rods (Y, Fig. 706). Lever A is telescopic, and carries a handle, E, which slides up and down, and carries with it the end of the clutch lever F, on which it slides, and in doing so changes the gear or works the speed-changing clutches. At the top position, the car is running at the top speed, and half-way held by a button catch, G, the motor is not in gear with the mechanism; when the handle is pushed to the bottom, the low-speed gear comes into operation. The bottom of the sliding handle carries a pinion, H, meshing with rack I, on bar J, thus being connected with and operating the throttle slide; when the handle is slightly twisted, the throttle is varied, and with it the speed of the car. Thus, slightly pressing the lever sideways steers the car, twisting the handle regulates the motor, and raising or lowering the handle changes the gear. Some Duryea cars, however, have what is known as a "two-hand control," in which a vertical steering column carries at the top a horizontal lever set across the car, whilst below the footboard its two arms connect direct by tensional connecting rods with the steering arms. To steer to the left, the end of the cross lever is pushed forward, whilst to steer to the right, it is pulled toward the driver; twisting the handle operates the throttle, and there is a separate lever with sliding handle for speed changing.

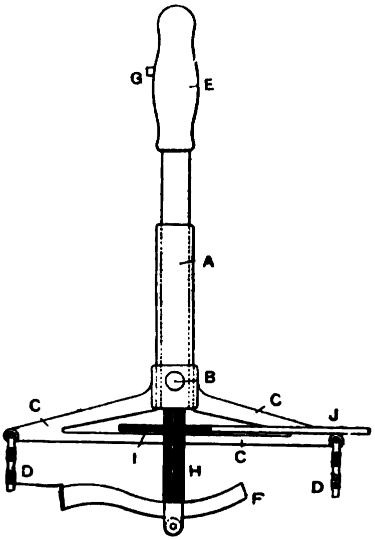


Fig. 711.—Duryea Steering Gear.

Pick cars are of two types, belt-driven and gear-driven, and each is made in two sizes, 6 and 10-h.p. The motor has two horizontal cylinders facing one another, but not in line, and bolted to the crank chamber. In the belt-driven machine, the flywheel is close to the crank chamber with a wide pulley outside it, the end of the crank-shaft being supported in a bearing carried by a bridge looping round underneath the flywheel. A belt drives a countershaft placed behind the live rear axle, and this shaft carries fast and loose pulleys, and spur wheels meshing with other wheels on the axle differential shell. For either of the two forward speeds, jaw clutches render either of the spur wheels rigid with the countershaft; for the reverse speed, a sprocket wheel is clutched to the countershaft and the differential on the axle is driven from it. The radiator tubes are arranged round the base of the bonnet, and a cam-shaft lying across the top of the motor drives the circulating pump. The band brakes are operated by means of a cam which, when rotated about its axis, tightens the two halves of the brake bands. In the gear-driven car, a friction clutch is mounted on the crank-shaft inside the flywheel, and from it a Renolds chain drives the first-motion shaft of the change-speed gear; this gear is mounted on a small tubular underframe, and gives three forward speeds and a reverse. The second-motion shaft is just behind the first-motion shaft, and carries on one end a brake drum and on its other projecting end a sprocket which chain-drives the live rear axle. In the 10-h.p. car one lever operates both forward and reverse speeds; and in the 6-h.p. car there is a separate lever for each of these. The descriptions of cars with vertical motors will now be resumed.

The Soames petrol car, made by the Langdon-Davies Motor Company, Limited, differs radically in many respects from any other car, and the side view of the chassis, Fig. 712, and the back and front views, Figs. 713 and 714, give evidence of originality. The most important innovation is the arrangement of the driving mechanism, including the motor and the change-speed gear, upon an entirely distinct underframe, which is suspended beneath the front and rear axles from semi-elliptic springs fixed to them. The body, the tanks, and the controlling levers are all fixed to the main frame, and it is suspended above the axles in much the usual manner. The controlling levers on the upper frame communicate with the parts which they actuate on the lower frame by means of flexible and ingenious connections. The method adopted for regulating the motor power, by hand, is interesting, and is described on p. 231.

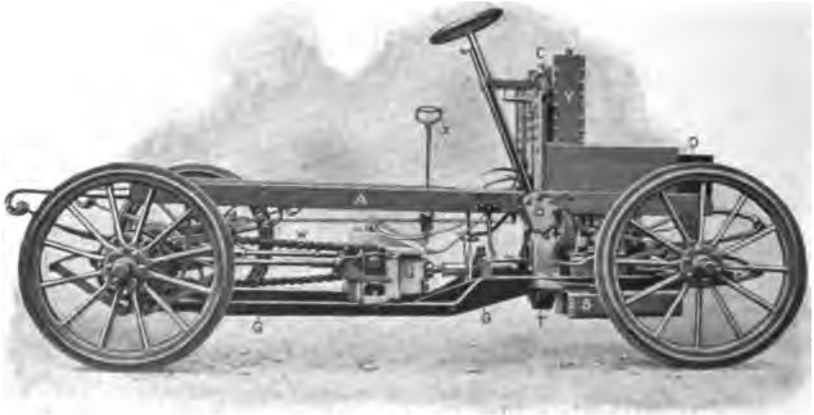


Fig. 712.—Side View of Soames Chassis.

The Soames main frame A is of section steel 101·6 mm. (4 in.) deep by 50·8 mm. (2 in.) wide, the metal itself being 9·5 mm. (·375 in.) thick. It is somewhat narrower in front than behind the driver's seat, and is stiffened with corner plates and by a cross member. The steering gear B is fixed to its outer surface, and the steering pillar is supported by a bracket fixed to the dash. The dash itself is made rigid by a steel forging forming its edge on this side of the car, and secured firmly at its lower end to the frame. The dashboard carries a combined water tank and radiator, C, and is perforated in order to allow the air to pass around the cooling tubes; the petrol tank D is fixed in front to the frame, which is supported by semi-elliptical side springs, E, between which and the axles are other semi-elliptical springs, F, but inverted. The inverted springs carry an underframe which has two longitudinal angle members, G, and a cross member, H J, at each end; the cross member, J, at the rear is of channel section, and its ends are connected with the side springs F by long links, K. The front cross member H is a forging which bows downward at its centre and ties the longitudinal members G together. The underframe has projecting horns, L, in front connected with the forward ends of the side springs F, and with brackets riveted to the members G for carrying the rear ends of these springs on shackles. The longitudinal members of the underframe are bent to a higher level in front than behind, and are stiffened across the bent

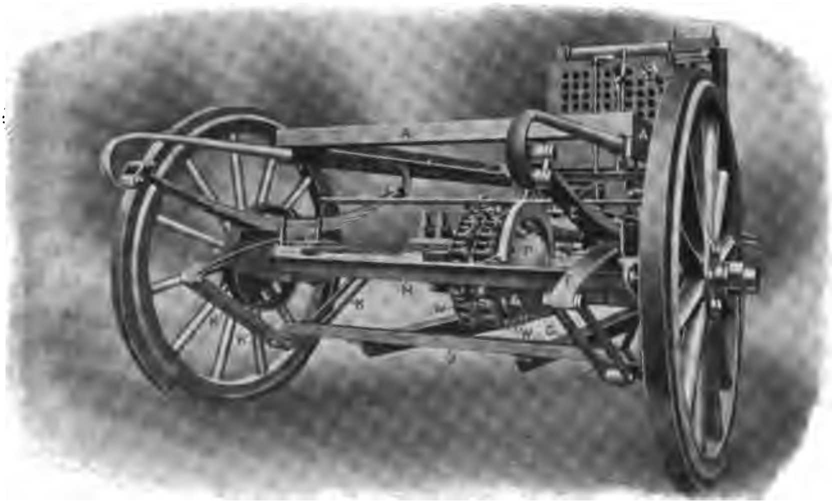


Fig. 713.—Rear View of Soames Chassis.

portions by flitch plates riveted against their inner faces. By this construction the underframe is quite distinct from the main frame, and is independently suspended beneath the axles; the weight upon it therefore tends to deaden any vibration of the wheels and axles, and the springs between them, and it prevents shocks from being transmitted to the mechanism. The rear axle is formed of two angle members, M, which connect the outside bearings at each end of the live axle together, and carry an intermediate bearing, N, between them. Together with the bearings and a bridge they form a very strong frame work in which the actual live axle O revolves. All the bearings are ring lubricated, and the outside bearings are exceptionally long. The two portions of the live axle are connected by a differential gear, P, containing four large planet bevel wheels. The front axle Q is quite straight and has the usual steering heads. The two-cylinder vertical motor is fixed to the underframe in front and develops about 11-h.p. at 800 revolutions per minute; its special system of governing is described on p. 231; R shows the cylinders. The cooling water is circulated through flexible pipes and the cylinder jackets from the radiator C by a pump friction-driven off the flywheel. The exhaust box S is fixed beneath the underframe in front, close up to the motor. The flywheel T forms the female member of the cone friction clutch, which normally is held in engagement by a spring. The connection between the pedal and the sliding portion of the clutch is so arranged that it is unaffected by the relative motions of the main frame and of the underframe. The gear box U is also fixed to the underframe, and is bolted down to the two longitudinal members G; distance rods connect it to the rear axle. In the change-speed gear the power is taken through bevel gearing to the first-motion shaft and through one or other trains of spur gears, always in mesh, to a second-motion shaft and then to the differential gear of the live rear axle O by a pair of heavy chains, W. The wheels on the second-motion shaft ordinarily run freely upon it, but either of them alternatively can be locked to the shaft by a sliding internal key. This method of rendering one or other spur wheel rigid with its shaft is already well known in connection with the M.M.C. cars and a few others, but in this case it is carried out in a different manner, and a special device is employed for fixing the sliding key firmly in place when it is in engagement with either wheel. Bowden wires, operated by handle X, slide the keys as required. A peculiar type of brake is operated by a pedal. It is fitted between the main clutch and the gear box, and consists of a disc against the edges of which a double lever presses instead of being a drum having a brake band. A handle, Y, on the dashboard enables the driver to lock the main clutch out of engagement when the car is standing still, thus allowing the motor to run quite freely at such times.

Cars with vertical motors are the only ones yet described,

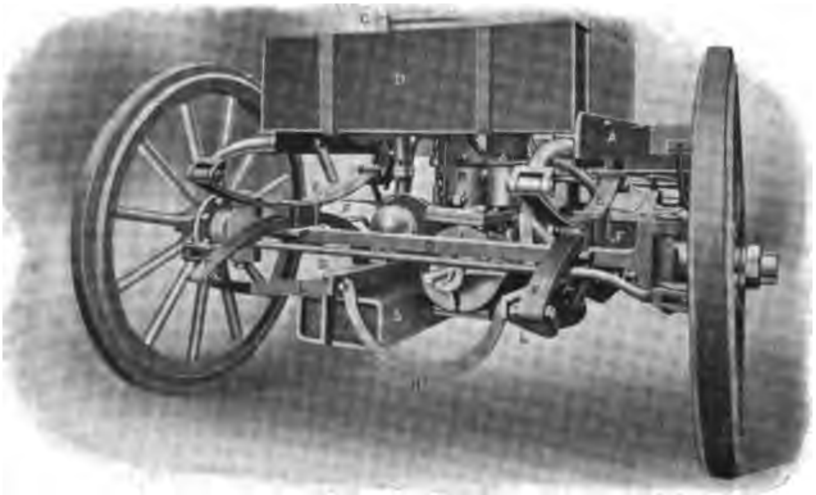
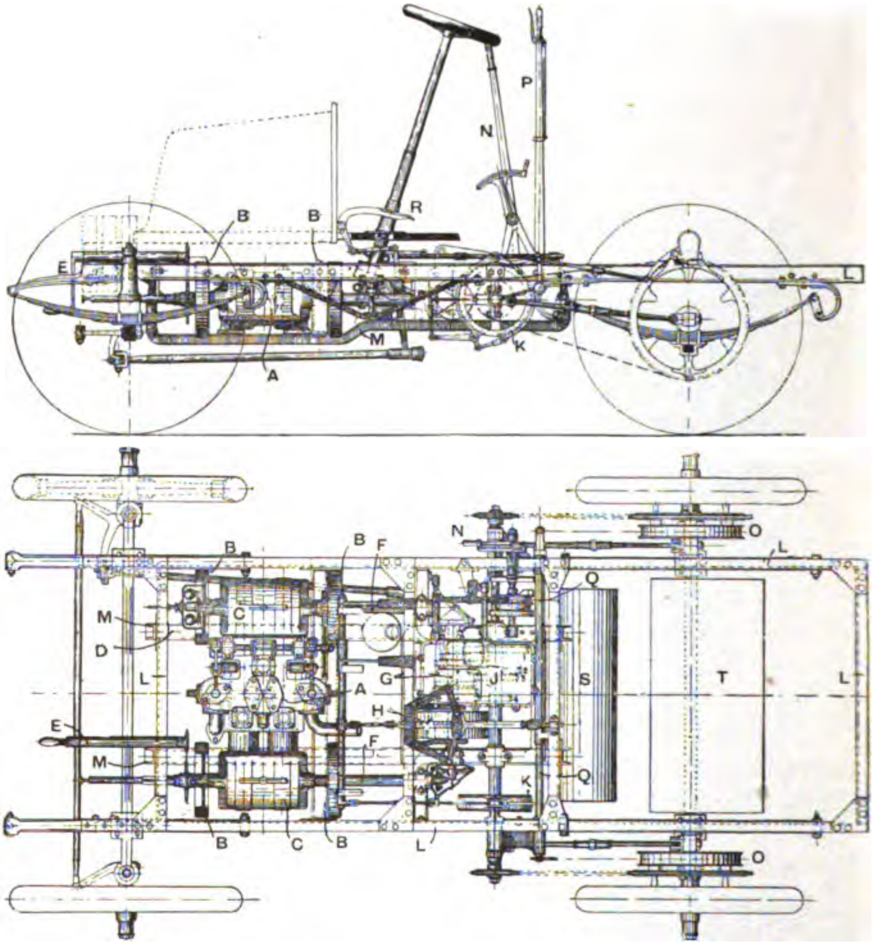


Fig. 714.—Front View of Soames Chassis.

the old Brouhot, Duryea, and Pick excepted; but space will now be devoted to cars in which the motor is of the horizontal type. These will be classified as was the other kind; that is, first will be described cars with side chain transmissions and fixed axles, then those with live axles driven by longitudinal shafts, and, finally, those with live axles driven by chains or other means.

Bardon cars employ the balanced motor described on p. 264 (where letter references A to E are explained), and are made in three types, one having an 8-h.p. single-cylinder motor, the second a 12-h.p. two-cylinder motor, and the third, a new model, a 5-h.p. single-cylinder motor; the distinctive features of the third model are summed up on p. 266. The first two are arranged much as in

Figs. 715 and 716, which show the second type. Letter references F to K are explained on p. 415, where the transmission and change-speed gear is described. The main frame L is of channel iron, and a narrow underframe, M, carries the two-cylinder balanced motor A



Figs. 715 and 716.—Elevation and Plan of Bardon Car.

and transmission gear. Speed-changing is operated by lever N, which is connected with a composite cam through a toothed quadrant. Side brakes O are operated by a second lever, P, which is connected with a rocking cross rod, Q, carrying a projection which comes into contact with the clutch mechanism and throws it out of engagement when the brakes are applied. Pedal R disengages the main clutch, and a second pedal does the same and also applies the countershaft band brake K. Steering is on the Ackermann principle, suspension springs are semi-elliptic, and road wheels are of the artillery type. All brakes are double-acting, and the side ones O are compensated by interposing spiral springs between the lever arms of the rocking cross rod Q and the brake band rods. A small lever inside the motor bonnet adjusts the auxiliary air supply to the carburetter and enables it to be shut off at starting so as to obtain a rich mixture; to avoid back fire when starting, the ignition hand lever is connected with a stop to prevent the starting handle from being turned unless the lever is at the "late fire" position. The petrol tank is under the seat, and the exhaust box S is low down behind the change-speed gear. The water tank T is further to the rear, above the back axle.

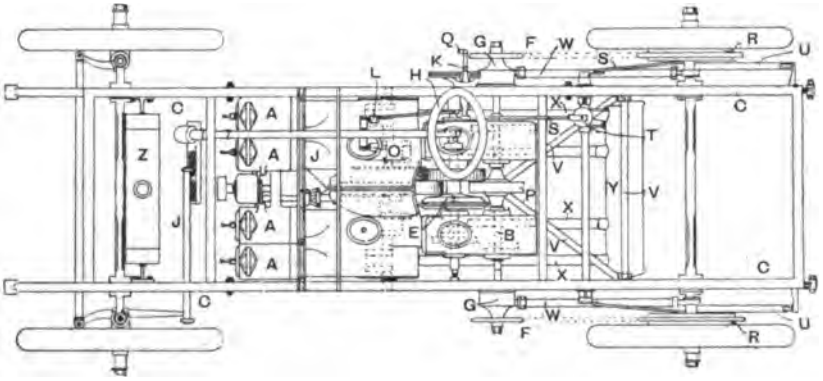


Fig. 717.—Plan of James and Brown Chassis.

James and Brown 9-h.p. and 18-h.p. cars are among the most original of English constructions, as will have been gathered from the descriptions of the elements already given. The 9-h.p. motor has two cylinders, whilst the other has four, and a plan view diagram of the chassis of the higher-powered car is presented by Fig. 717. There being no underframe, the horizontal motor A and gearing B (both fully described on pp. 266 and 415) are pivoted from the steel-flitched main frame C. The flywheel is on the longitudinal centre line of the car, with the result that there is no tendency due to gyrostatic action for the car to steer more easily in one direction than the other. The change-speed gear and transmission are fully described on p. 415; E is the main clutch, which is a special feature (*see* p. 372). The final drive is by chains from side sprockets F, whose large bearings are shown at G. Fig. 717 is more intelligible when compared with Fig. 419, p. 414, which shows the motor and transmission gear of the two-cylinder chassis. The steering wheel H works through the connections J; K is the change-speed lever, L the clutch pedal, O the pedal operating the countershaft brake P; Q is the lever that applies the side internal brakes R through rods S; T is the brake compensating pulley, and U the brake tension rods, and the construction of the brake itself is dealt with on p. 489. The tubular stays V take the strain of the countershaft brake, and the distance rods W take the chain thrust. The pipes X lead the exhaust to the silencer Y. Z is the radiator and tank. The James and Martineau patents control the manufacture of this most interesting car.

The Roots 4½-h.p. car with detachable back seat is illustrated in side elevation by Fig. 718. The Roots system of using ordinary paraffin is fully described on p. 273. In the car here shown, the motor is under the front bonnet, and has its crank shaft parallel with the axles; its speed is 700 revolutions per minute. The drive is through a clutch and chain to a gear box providing three forward speeds and one reverse, and the countershaft chain drives the rear road wheels as indicated. The artillery wheels are 76·2 cm. (30 in.) in diameter, and have solid rubber tyres. The fuel tank holds 9 l. (2 gal.). The 12½-h.p. car has a two-cylinder vertical motor in the same position and running at same speed as above. The frame is of channel steel, and there are four forward movements and one reverse. Sufficient oil and water is carried for a journey of 161 km. (100 miles), the oil consumption being about 4·5 l. (1 gal.) per hour. Ignition is by magneto, platinum tubes being fitted as a stand-by. The weight is 1 ton.

Wolseley standard cars are of 5 h.p., 10 h.p., and 20 h.p., their motors respectively having one, two, and four cylinders, and all having a cylinder bore of 114 mm. (4·5 in.) and a piston stroke of 127 mm. (5 in.). All the cars are built on similar lines, though varying in detail. A further type is a 7½-h.p. car with a two-cylinder motor. There is also a 30-h.p. racing car. In all, the leading features are a horizontal motor situated in front beneath a bonnet, a large main friction clutch in the fly-wheel, and chain transmission to the change-speed gear (*see* p. 396), from whose countershaft there is the usual chain-drive to the rear road wheels. Other features of interest are the steering gear (*see* p. 446) and the side and countershaft brakes (*see* pp. 489 and 491). Figs. 719 and 720 are elevation and plan of the 10-h.p. car. The frame A is of channel steel. The two-cylinder motor B, carried by cross members of the frame, has a crank shaft, C, on which is the main friction clutch D (operated by pedal A^2, through the adjustable rod A^3, Fig. 399, p. 397). The change-speed gear E is described on p. 396, but it may be said that F represents the rotating shaft that brings the various trains of wheels into mesh as required; it is operated by hand lever G through its quadrant H, and spur-wheel J. Shaft F carries two cams, K, L; the former is outside the aluminium gear case, and operates the jaw clutch inside the sprocket wheel M; the latter, L, inside the gear case slides the change-speed wheels. A fixed steel shaft, N, acts as a guide for the three portions caused to slide along it by the cams. The first-motion shaft, indicated by dotted lines, O, carries the sliding gear wheels, and is driven by a Renolds chain P from the motor shaft. The differential countershaft Q is wholly enclosed by the gear case, and on it is the double-acting band brake R, operated by a pedal. It is to be noted that separate pedals (F^1 and A in Fig. 399, p. 397) operate the main clutch and

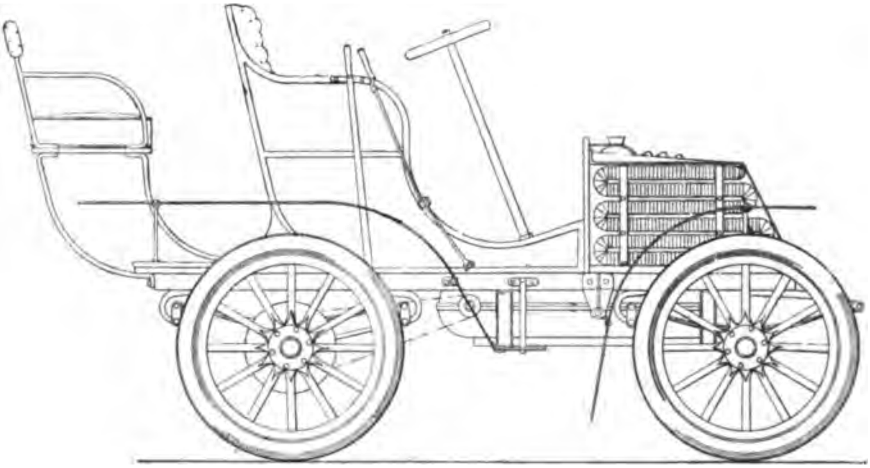
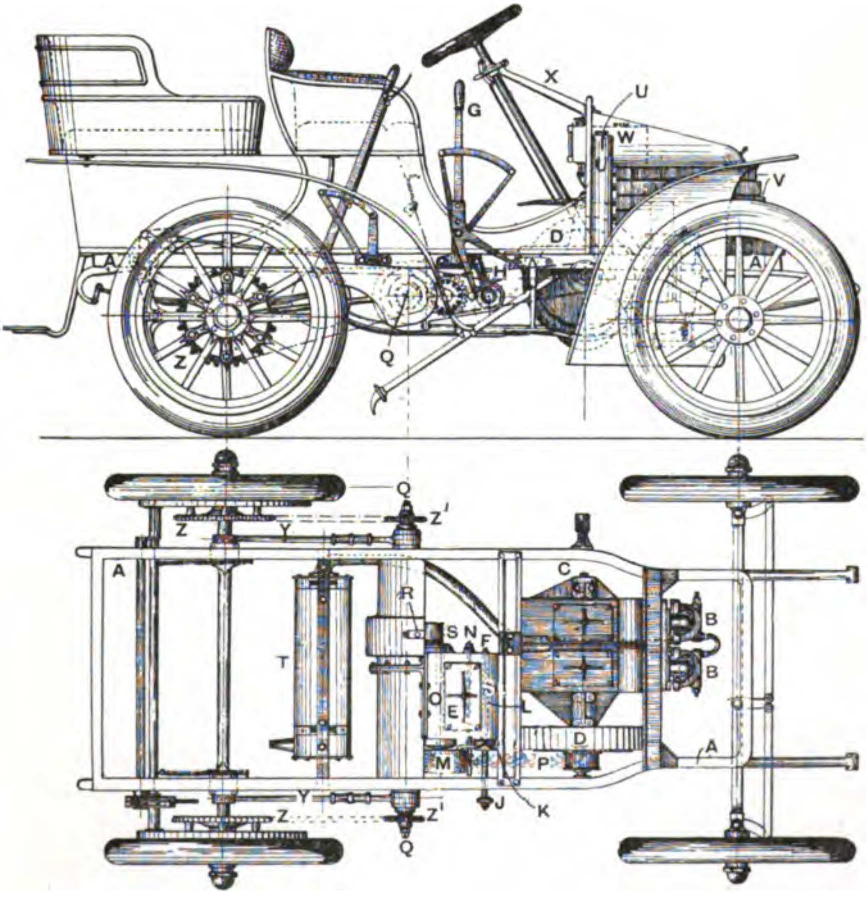


Fig. 718.—Elevation of Roots Petroleum Car.

the countershaft brake; the drum of the latter, S, is hollow so that it can be water-cooled. The main frame A is supported by semi-elliptic springs. The exhaust box T is placed across and beneath the frame. Multiple feed lubricators of aluminium are fixed to the dashboard and are connected by pipes to the various bearings, there being a separate sight feed to each pipe, whilst a gauge glass shows the height of oil in the reservoirs. Two vertical reservoirs, U, one each side of the dashboard, carry the cooling water, and are connected together by horizontal radiating tubes, V, forming the front and sides of the bonnet; the tubes have square gills, and by forming steps in front add to the appearance of the car; these combined reservoirs and coolers carry 4·54 l., 6·8 l., and 9 l. (1, 1·5, and 2 gal.) on the 5-h.p., 10-h.p., and 20-h.p. cars respectively. A circulating pump, on the principle of a Roots blower, is driven by spiral gearing from the motor cam shaft; but if this failed, the circulation would be natural the water supply being at a higher level than the motor cylinders. Between the two reservoirs U, and under the bonnet cover, is a petrol tank, W, and on the dashboard in view of the driver is a petrol gauge; the two are connected through a three-way cock (operated through arm X) which is in connection also with the carburetter. The gauge glass shows the level of petrol in the tank, and the three positions of the cock allow of (*a*) supply to glass and carburetter being cut off; (*b*) petrol to flow only to carburetter; or (*c*) carburetter to be connected to gauge glass. For tightening the motor chain P the gear box is slid along the frame, and for the side chains the swinging distance rods Y, connecting gear box with back axle, can be adjusted. The road wheels of the artillery type run on ball bearings, the driven sprockets Z, chain-driven from sprockets Z^1, riding on the rear wheel hubs and being bolted to alternate spokes. The side brake work, operated by the lever to the rear of speed-change lever G, will be understood from Figs. 719 and 720.

The special attention given to the design of external features in the Gillet-Forest car is repaid by the smart appearance, but the whole car with its mechanism is an interesting piece of work. The carburetter, single-cylinder horizontal motor, and ingenious system of water cooling are described and illustrated on pp. 150, 261, and 196 respectively. Two sizes of motor are made—6 to 7 h.p. and 9 to 10 h.p.—and the bodies that may be placed upon the standard chassis are in a great number of different designs. The tubular rectangular framework is built solid with the brackets that carry the various parts; the tube carrying the inclined steering pillar is brazed into a malleable casting forming part of the frame, and containing the bearings for the steering gear. The motor half-speed driving shaft (*see* p. 261) is mounted in line with the first-motion shaft of the change-speed gear, which is of the sliding spur-wheel type, and power is transmitted from the gear to a live rear axle by a universally jointed shaft. In Fig. 721 B is the case of the longitudinal shaft, C the differential case, D the axle casing, E the wheel nave, and M distance rods. There are double-acting band brakes acting on each



Figs. 719 and 720.—Elevation and Plan of Wolseley Car.

of the two drums T on both sides of the car, and their arrangement is highly ingenious. The weight of each band is taken by a spiral spring held by an arm projecting upwards from the spring clips (the method of securing the suspension springs is interesting and is clearly shown); the fulcrum point of each brake is carried by a tie rod, P, passing from a point below the centre of the axle to a pivoting point on the frame. Each rod takes, in tension, the whole of the twisting strain imposed by applying the brakes during forward motion; and the fulcrum point is too low for the rods to be buckled over when in a state of compression due to the brake action when the car is travelling backwards. The outer brake is worked through rod K from a side hand lever; the inner one is worked by a pedal. The exhaust box containing cylindrical, perforated baffles, is shown partly cut away in Fig. 721.

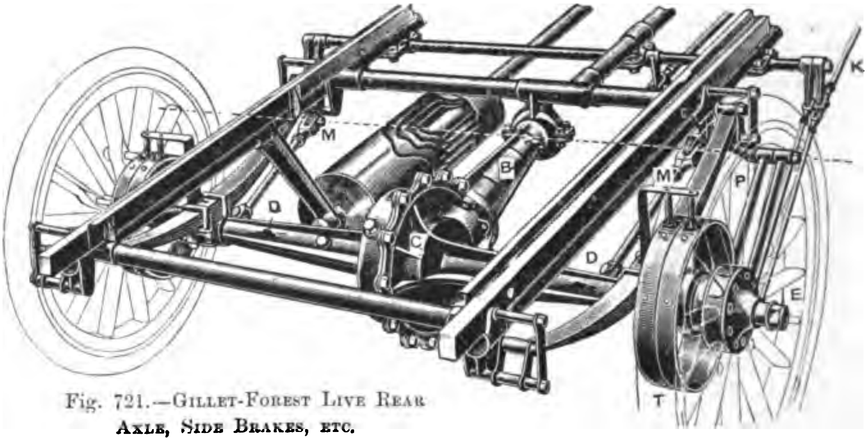


Fig. 721.—Gillet-Forest Live Rear Axle, Side Brakes, etc.

The Autocar (an American vehicle) has a horizontal balanced motor whose two cylinders A are opposed but not in line, so that the central connecting rods work straight on to the cranks; the half-speed shaft and its driving spur wheel are mounted inside the crank chamber B, and as the cam directly operates the exhaust valve rods, the ends of these, the half-speed shaft and its driving gear, are all lubricated on the splash principle in the crank chamber. The special float-feed carburetter C is described on p. 135, and the exhaust silencer D on p. 205. Of the two fly-wheels E F, the rear one E contains the clutch, from which there is the usual transmission to the gear box G, hung from cross stays secured to the channel-steel main frame, which is reinforced with wood. The drive is through shaft H and bevel gearing to the differential J on the live rear axle. There is a direct through-drive on the top (third) speed. There is a band brake, K, on the longitudinal shaft H. To prevent the pressure rising in the crank chamber above that of the atmosphere and so forcing the oil past the pistons into the cylinders or out through the bearings, a small pipe containing a ball non-return valve leads out of it. There are double elliptic springs at both rear and front, and in the latter a quarter-elliptic spring L replaces the usual horn bracket. Brake K and side internal type brakes M are operated by pedals N O respectively.

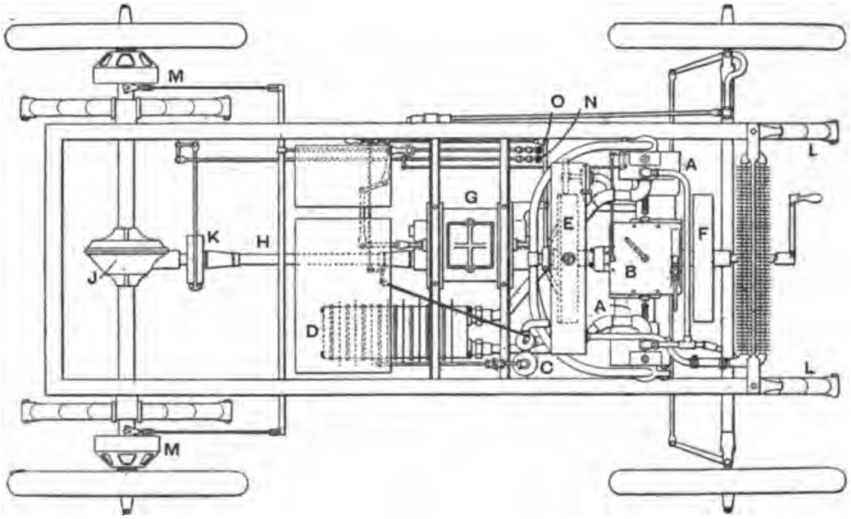


Fig. 722.—Plan of Autocar Chassis.

The Wilson and Pilcher 10-h.p. car has ingenious details; the four-cylinder balanced motor is fully described on p. 270, and the novel transmission gear on p. 413. The radiator is carried obliquely at the back.

The Packard 12 brake-h.p. car is a well-known American type, whose chassis is clearly illustrated by Fig. 723. The horizontal single-cylinder motor has a water jacket composed of a thin corrugated copper sleeve, the cylinder head and crank case being all cast in one piece. The inlet valve is easily removed from the cylinder head together with its seat by taking the nuts off its holding studs. This can very quickly be accomplished for inspection or regrinding. Bevel gears drive the half-speed shaft, which itself drives the water circulating pump, ignition timing gear, and exhaust valve cams. The crank-shaft is a steel drop forging turned to shape and then ground true. The connecting rod has large bearings at each end. The sliding spur-wheel change-speed gear gives three forward speeds and a reverse, all operated by one lever, and the shafts run in phosphor-bronze bushes, the lower gear wheels dip in oil, and so lubricate those on the upper shaft, this latter being the first-motion shaft. A simple interlocking device prevents the shifting of a gear until the main clutch has been first released. The drive between the motor and transmission is through a system of coiled springs in the flywheel, as illustrated in Fig. 723, which absorb the jerkiness of the motor's impulse. The main clutch is of the friction three-plate type, the two outside plates being connected to the first-motion shaft, and when engaged, clamping the centre plate; the latter is driven by the flywheel through the medium of the coil springs. The starting handle is connected at the side, as shown, to the upper change-speed gear shaft, the lower shaft carrying a driving sprocket on its inner end, and a large brake drum on its outer end. From the sprocket a roller chain drives the differential of the live rear axle. Front and rear axles have both ball and roller bearings, and the artillery wheels are 86·4 cm. (34 in.) in diameter, the pneumatic tyres being of 10·16 cm. (4 in.) section. The frame is of channel steel, and the spring suspension is peculiar. At the rear are two elliptic springs, in which provision is made for moving the rear axle when adjusting the chain without affecting their action. The front spring is of the X type, and the combination is claimed to allow of any one of the four wheels being 38 cm. (15 in.) without straining the body or mechanism. There are the usual distance rods, and steering is by wheel with worm and segment. The lubricating oil, water, and petrol tanks are under the "dummy" bonnet in front of the dash, as illustrated. The wheel base is 206 c.m. (81 in.). The four-cylinder car is of quite a different type, and is described on p. 638.

The Winton 20-h.p. car (American) has a main frame of sheet and angle steel riveted together. The motor is on one side, about midway between front and rear axles, and is of the two-cylinder balanced horizontal type, with cylinders enclosed in large water jackets, which may be regarded as being small water tanks. The crank-shaft lies across the frame, and is in line with, and drives through, a disc friction clutch, the first-motion shaft of the gearing enclosed in a gear box. The flywheel is a part of the clutch which is operated by a sliding cone on the shaft which causes pivoted levers to force the friction surfaces together. A sleeve carrying a sprocket wheel rides freely on the projecting end of the first-motion shaft outside the gear box between it and the clutch, and from this sprocket a chain drives the live rear axle. The top speed is obtained by clutching the sprocket direct to the first-motion shaft. In the gear box is a short lay shaft, parallel with, and in the same horizontal plane as, the first-motion shaft. At one end of the lay shaft is a fixed spur wheel always in mesh with a corresponding wheel on the sprocket sleeve; also there are two unequal spur wheels meshing with others on the first motion shaft, and either of them can be clutched rigidly to the shaft so as to obtain the first and second speeds respectively. The motor speed is regulated by a pneumatic device in which air is forced behind a piston which throttles the ingoing mixture. The faster the motor runs, the greater the air pressure behind the piston, and so the desired speed is maintained automatically. There is, however, an accelerator, and when its pedal is depressed a bye-pass valve on the

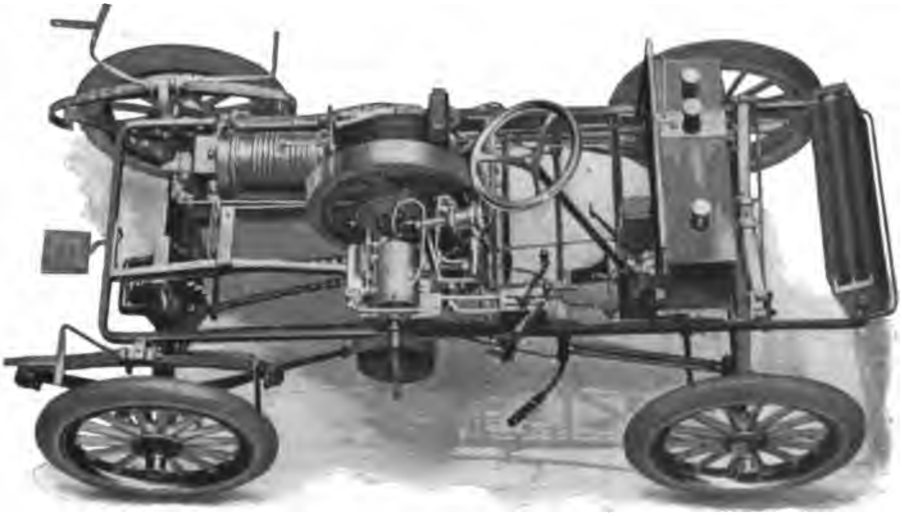


Fig. 723.—View of Packard 12-h.p. Car.

air pipe is opened progressively; it can be closed entirely by a small handle, and then the motor stops. The handle can open the bye-pass valve only enough to allow the motor to run at a very low speed, the higher speeds required when driving the car being obtained entirely by depressing the pedal. A surface carburetter is employed. The motor is lubricated by pipes leading from a small tank above the crank chamber, and the flow of oil to this tank from the main reservoir is controlled by a float-feed device. Petrol, water, and lubricating oil tanks are all beneath the bonnet behind the multitubular radiator. The removable starting handle can only be inserted in place after the moment of ignition has been retarded, and this prevents risk of back firing whilst using it.

The Hermes 15-h.p. car has a main frame of heavy channel steel, A, Fig. 724, and cross tubes B carry the horizontal motor C (*see* p. 267), whose two cylinders, not quite opposite one another, are one in front and one behind the crank chamber. The motor is to the left of the frame, the crank-shaft D is across the car, and the fly-wheel clutch E is almost in the centre of the car. A flexible coupling connects the clutch to the gear box F placed to the right of the frame. The spur wheels on the first-motion shaft are rigid with it; those on the second-motion shaft revolve freely except when the shaft is slid along, spring catches in the spur-wheel hubs engaging with slots in the shaft. The two shafts are in the same horizontal plane. The differential gear G, on the inner end of the second motion shaft, is not enclosed in the gear box; around its shell is a brake drum, and on either side of it is a sprocket, H, an enclosed chain passing from each one to a half of the live rear axle J. The case of the driven sprockets is shown at K. The object in having the differential on the cross shaft instead of the axle is to reduce its size and the strains imposed upon it, and to allow of running it at a higher speed. The side brakes, merely indicated at L, are compensated by a steel cable passing across at the back; and a safety pawl can be brought into contact with a ratchet wheel in one brake drum, and so prevent the car running backwards downhill; to withdraw the pawl, the car must be stopped. The width is unusually great, the track being 155 cm. (5 ft. 1 in.). The exhaust pipes M lead to the silencer N at the rear. Other cars are of 18 or 24 h.p.

The Lanchester petrol car, which is clearly shown in sectional elevation by Fig. 725, p. 678, in half plan by Fig. 726, and in back elevation by Fig. 727, p. 679, is entirely British in its design and manufacture, and made its first appearance in 1899, when it won the gold medal at the Richmond trial; it is one of the instances in which a complex piece of mechanism has been worked out entirely on first principles before any attempt was made at construction. Although since its first appearance the car has been altered in many details, the principal elements remain as they were first invented. The following description of the car is adapted from one which appeared in *Engineering*. In Fig. 725 the position of the propulsive mechanism is indicated by dotted lines. The characteristic features of the car are: A wick carburetter (*see* p. 116), a two-cylinder horizontal motor (p. 263), balanced in an unusual manner, special magneto-electric ignition in which a device is incorporated for securing certainty of sparking, and cylinder cooling by means of a fan. The transmission is by a longitudinal shaft with universal joint driving a live rear axle through worm gearing. The method of suspension is entirely different from horse carriage practice. Change of speed is effected by epicyclic trains put into action by means of clutches or brakes. The steering is by a side lever or tiller. The Lanchester car is essentially a touring carriage, and only one type is made, this having a 16-h.p. motor, and possessing three forward speeds, 45, 25·7, and 11·3 km. (28, 16, and 7 miles) an hour, and a reverse speed of 14·5 km. (9 miles) an hour. The whole of the mechanism is placed underneath the car, and there is no need, therefore, for a platform extended forward and covered by the usual bonnet. This gives

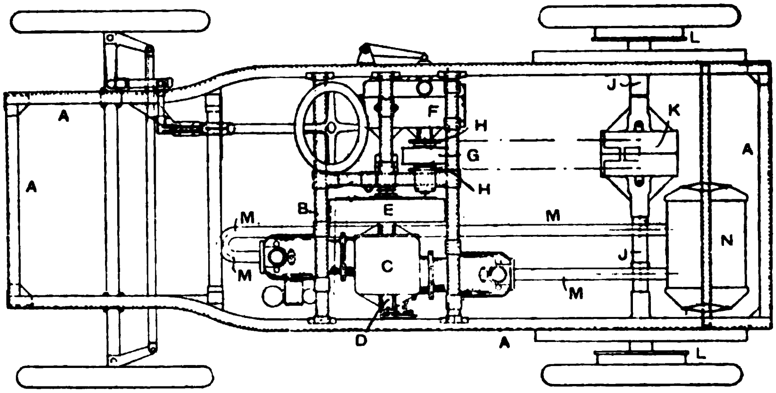
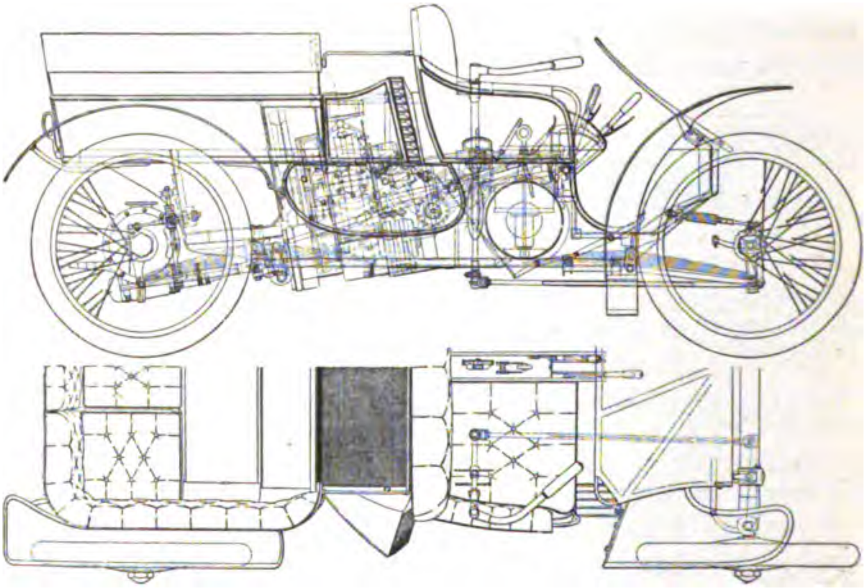


Fig. 724.—PLAN OF HERMES CHASSIS.

additional seating capacity for a given length of car body and motor space. The mechanism is made accessible by having between the tonneau body and the front seat a short space covered by a "deck." At the sides are the wind scoops, with a louvre front through which the cooling air for the cylinders is drawn. These scoops hinge at their bottom part, and can be dropped down by removing a small peg or dowel. The deck can then be lifted off, and the main part of the mechanism most often requiring attention thus exposed. The front seat can be lifted bodily off by sliding it backwards about ½ inch, and the whole of the actuating mechanism in front of the motor, as well as the carburetter and oil tank, is then exposed to view. The tonneau body may next be removed by taking out a dowel and lifting it off. The whole of the chassis may thus be exposed by a couple of men within a space of about five minutes. The motor has two crank-shafts, placed one above the other, and each has its own flywheel; the two pistons are each connected to the two crank shafts by two connecting rods—that is to say, each piston has a double connecting rod, one element of which is attached to one of the two crank pins. The balancing of the cranks is described on p. 263. The


Figs. 725 and 726.—Elevation and Half Plan of Lanchester Car.

two flywheels revolve in opposite directions, and neutralise the action of the motor due either to the inertia of the moving weights or the impulse from explosion. The two crank-shafts are geared together by spur wheels to get the proper distribution of load. The practical result of these devices is that a very smoothly running motor is obtained ; when the car is standing still there is very little vibration indeed. The motor governor is of the inertia type, and depends for its movement on the fact that it will lag when the motor runs above a certain speed. In that case the tappet does not strike on the end of the valve stem or catch plate. Low tension current for ignition is generated by a magneto-electric machine having permanent magnets attached to the flywheel of one of the motors, the armature remaining stationary. The magnets, therefore, act as the flywheel, so that there is no restriction in regard to their weight. The magnetic circle is completed by the rim of the wheel, and the north and south poles are consequent poles formed at the middle of each magnet bar (*see* Fig. 251, p. 265), the effect being, of course, similar to that of two horse-shoe magnets placed together. Current is induced in the armature coils as the poles of the magnet break the magnetic circuit as they revolve. On the armature there are four coils forming two independent circuits, each consisting of a pair of coils in series. One end of each of these circuits is connected to part of the car which forms earth. The other terminals of the coils are attached to the fixed conductors, leading to the ignition mechanism. The sparking plug can be removed and replaced with great facility, a gas-tight joint being formed after the manner of a breech-locking mechanism. The conductors used are insulated steel bars, there being no wires for the purpose. The circuit has two parallel branches, one outside and one inside the cylinder ; in the former, contact is made by means of a wiper or tweaker, which is brought in contact with the flat spring. The tweaker revolves with the side shaft of the motor, and wipes the

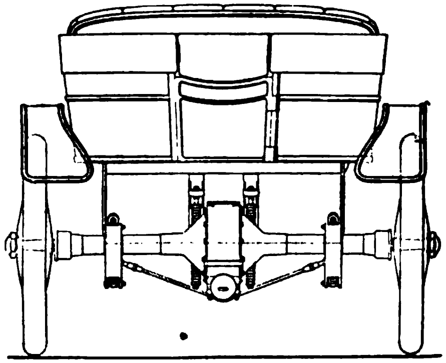


Fig. 727.—Rear Elevation of Lanchester Car.

igniter spring at every two revolutions of the engine. Each time the tweaker comes against the spring the igniter wire in the interior circuit is forced into contact with the anvil inside the combustion port. When the tweaker passes the spring, the latter flies back suddenly, thus causing an extremely rapid rupture of the outer circuit. The outer contact, between the tweaker and the spring, breaks first, and the inner contact for a very minute fraction of a second has to take the whole current, when it also breaks. In this way a stout flaming spark is obtained, and the external contact, which is accessible, and is not in the explosive gases, can always be kept clean, and is capable of taking the whole current easily, so that assurance is made that an ample current is always passing. As this contact breaks first, the whole extra current is forced to pass through the sparking plug, which ignites the carburetted mixture. The internal contact may be dirty or rusty, and its resistance may be very high, but there is always a good path in the outer circuit for the current, and on that path being broken there is a sudden rise in the electromotive force, producing a spark which leaps across the inner contact with great force. The width of the spark gap is adjusted by means of a screw, the head of which is slotted.

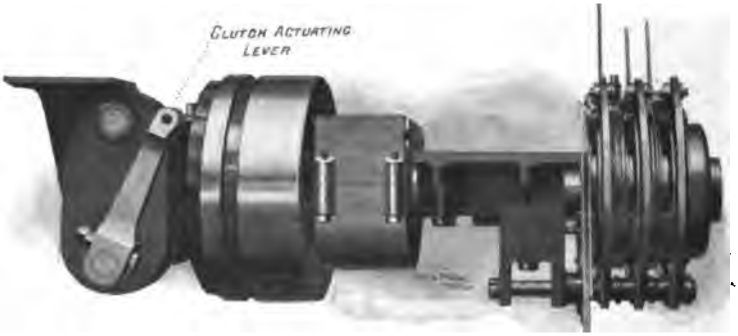


Fig. 728.—Elevation of Lanchester Countershaft.

The Lanchester countershaft and transmission gear is shown in perspective view, elevation, and plan by Figs. 728 and 729. The transmission of power from the motor is to an independent worm shaft placed on the underframe, and connected by a universally jointed shaft. The shaft is carried by a bracket bolted by four bolts to the underside of the motor baseplate. Power is conveyed from the lower motor crank-shaft by means of helical gearing, the driven wheel being protected by an aluminium gear case, and constantly running in oil. It is always in gear with the motor, and is keyed upon a hollow shaft running in bearings in the bracket. Between the two bearings there is a thrust bearing with balls to take up a longitudinal thrust of the cone clutch. The clutch shell is attached to the helical wheel, and is therefore always in gear with the motor. The clutch cone slides on a central shaft which passes through the hollow shaft, and which is articulated by means of the jointed shaft coupling to the worm shaft which actuates the road wheels. This internal shaft, as it passes completely through the hollow shaft, actuates the change gear shown at the right-hand side of Fig. 729. The hollow shaft, to which is attached the outer element of the clutch, is always running, being in connection with the motor, whilst the centre shaft, to which the cone part of the clutch is attached, as well as parts of the change-speed gear, is in constant gear with the road wheels of the car. On the left-hand side of Fig. 729 is shown the main brake, the brake ring being indicated; the recesses shown are to hold grease. This brake consists of a fixed double cone, which engages in a corresponding recess in the clutch cone. When the clutch cone is

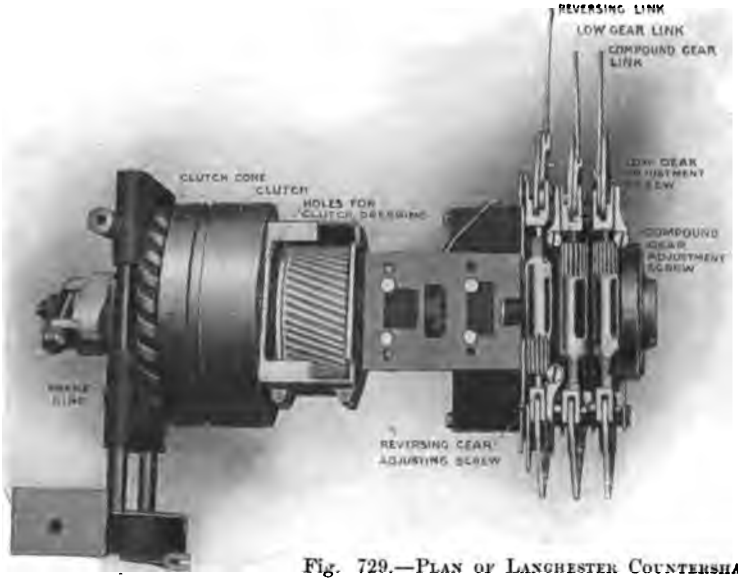

REVERSING LINK
LOW GEAR LINK
COMPOUND GEAR LINK
LOW GEAR ADJUSTMENT SCREW
COMPOUND GEAR ADJUSTMENT SCREW
CLUTCH CONE
CLUTCH
HOLES FOR CLUTCH DRESSING
BRAKE RING
REVERSING GEAR ADJUSTING SCREW

Fig. 729.—Plan of Lanchester Countershaft.

pushed to the right it puts the driving mechanism in gear, so that the car starts directly. When the actuating lever is put in a central position, the cone does not engage at all, and the motor runs freely without propelling the car. When the cone is pushed back, it becomes in turn the outer element of a clutch or brake, the internal part being fitted to the car frame; the whole driving of the car, excepting, of course, the steering, can thus be done by one handle under ordinary conditions. For dealing with gradients, however, and for going backwards, change-speed gearing is naturally necessary. This is shown on the right-hand of Fig. 729, and is worked from the driver's seat by a separate lever. Trains of epicyclic gear are used, and in two of these gears the central element is formed by means of teeth cut in the end of the hollow shaft, these teeth gearing into the planet wheels of the epicyclic gear. For the reversing mechanism the planet wheels are mounted on pins on the friction drum enclosing them, whilst in the low gear the planet wheels are on pins carried on the centre shaft. In the reversing gear the outer element is connected to the centre shaft, whereas in the low gear the outer element forms the friction drum. The compound gear, which gives an intermediate speed, forms a train of its own, and is mounted on the extreme end of the centre shaft. It interacts between the end of the centre shaft and the low-gear friction drum. These gears are put into action by means of the connecting links shown, causing a clutch action to take place. They are all controlled by one handle close to the driver's seat, so that the entire operation of the car, including reversing, may be carried out by means of this lever, supposing high speed not to be required. In Fig. 729 the gear adjustment screws shown are for taking up slack due to the wear

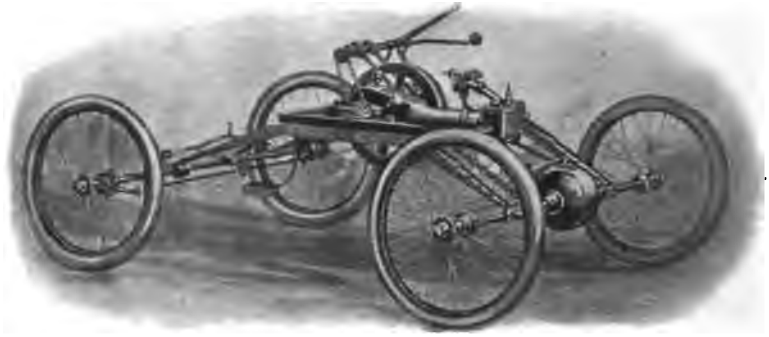


Fig. 730.—Chassis of Oldsmobile Car.

of the frictional surfaces. They have slotted heads, and the worm of the screw engages with the fluted ends as shown. The countershaft is lubricated by a pump. In the clutch mechanism, both plate and clutch surfaces are of cast iron. The change mechanism is always in mesh, and the frictional parts of the change gears is cast iron or hardened steel. With regard to the steering, the steering wheels are mounted on short axles on the Ackerman principle, and connected so that they turn together. The connecting rod from the steering handle, or tiller, is attached to the bottom lever. Wire spoked road wheels are employed.

The Oldsmobile is an American petrol runabout of distinctive design, as evidenced by the view of the chassis, Fig. 730. A section of the car is shown by Fig. 731, and a description of the running gear is given on p. 417. Motor and change-speed gear are secured in a channel steel rectangular frame, A, mounted on two composite leaf springs, B, which connect the front and rear axles C D. The body E is secured to the frame A by bolts provided with rubber blocks, which act as cushions. The one-cylinder horizontal motor with fly-wheel, F, and enclosed crank chamber, G, is mounted in line with the epicylic change-speed mechanism (*see* p. 417), which gives two forward speeds and a reverse, changes of speed being brought about by tightening band brakes and working a clutch as previously described. One lever, H, does all the speed changing. A chain, J, drives the differential on the live rear axle. The motor half-speed shaft is worked by spiral gear,

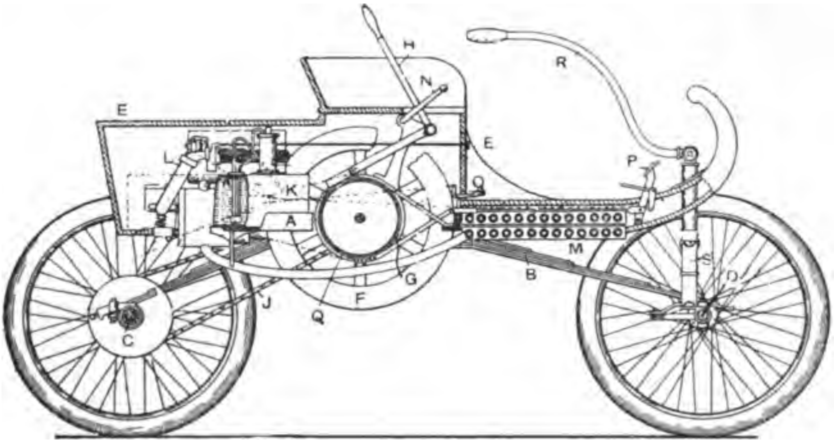


Fig. 731.—Section of Oldsmobile Car.

and inlet and exhaust valves are operated mechanically. Though the petrol tank K is below the level of the carburetter mixing chamber L, the convenience of a gravity feed is obtained in an ingenious way, made clear on p. 140. The exhaust box, described on p. 205, is singularly effective. The motor cooling water is forced by a rotary pump through a horizontal plain tube radiator, M, arranged in front of the car under the dash; the pump is driven through a flexible connection from the motor shaft. The motor can be started from the seat by handle N. Pedal O reduces compression at starting by lifting the exhaust valve. Another pedal, P, works the band brake Q. The steering tiller and connection are shown by R S. At a speed of 1,000 revolutions the power is about 4 h.p., and the weight of the car is about 356 kg. (7 cwt.)

Two examples of cars whose live axles are driven by spur gearing will now be described.

The Haynes-Apperson car has been known in America since 1893, and in its latest form it possesses some interesting features differing from European practice. The angle iron frame has cross tubes at the rear end for supporting the motor and gearing, and an underframe consists of two solid reaches connected to each end of the live rear axle, and coming together to form a swivel-jointed connection at the centre of the front axle. The two-cylinder balanced horizontal motor of 127 mm. (5 in.) bore and 152·4 mm. (6 in.) stroke, is to the left of the vehicle, and its crank-shaft directly drives the first-motion shaft, on which fixed spur wheels mesh with loose wheels on a shaft immediately below. All the loose wheels have ingenious band-brake devices, and can be fixed at will, so as to drive the second-motion shaft on whose inner end is a sprocket wheel from which a chain passes to a second countershaft above the live rear axle, the final drive between countershaft and axle being by means of two spur wheels. There are three forward speeds and a reverse. This was the first American car, it is believed, to employ wooden road wheels. Roller bearings are used throughout the car, except the main bearings of the motor; the crank-shaft bearings are of the roller kind. The aluminium radiator is tubular, rectangular in form, and has 9·2 m². (100 sq. ft.) of radiating surface; its weight is about 15 kg. (33 lb.). The new steering system consists of the usual steering pillar with wheel or tiller, a novelty being the steering box, which is attached to both the pillar and to a tube crossing the car a short distance below the floor line in such a manner that the steering pillar rotates about this tube. By this means the steering pillar may be put in a vertical position or it may be inclined as desired, a small toe latch maintaining it in any angle. The steering pillar, just before piercing the floor, passes through a brass ball rotating on pins piercing it at opposite sides. These pins are attached to a brass sliding plate, which moves backward and forward through a grooved brass guide, and so steadies the column.

The Arroll-Johnston 12-h.p. car is highly ingenious as regards its general arrangement. The motor has two horizontal cylinders, each containing two pistons, and is water-cooled, a radiator of horizontal Clarkson tubes being beneath the front of the car. The petrol tank is in front, but the motor and gearing are at the back and high up. For the most part, the main frame is of T-section steel. The main clutch is on one end of the crank-shaft, and the flywheel on the other, and the sliding spur-wheel gearing is enclosed in a casing beneath. The first-motion shaft is chain-driven from the motor, and the second-motion shaft drives by means of a second Renolds silent chain a small lay shaft carried upon the live rear axle. The lay shaft drives the differential on this axle by enclosed spur gearing. The gear wheels on the first-motion shaft are fixed, those on the second-motion shaft are sliding, and for the reverse there is an intermediate spur wheel, all four forward speeds and the reverse being operated by a single side lever which works through three cams. The rear wheels run on ball bearings introduced between the hubs and the steel tubes which enclose the live axle; thus the stationary portion of the axle takes the weight of the car. The motion is governed on the hit-and-miss principle and by an uncommonly sensitive inertia governor, which cuts out one cylinder before the other. A special accelerator is operated by turning round the handle of the change-speed lever. Low-tension igniters take current from a magneto, and the carburetter is of the Daimler float-feed type. The two cranks are opposite to one another, and the two forward pistons are connected with the one crank pin and the two rearward ones with the other. A small force pump lubricates most of the motor's moving parts, these being enclosed and having through passages to their bearings. A wick lubricator is mounted above the cylinders, and four separate pipes lead from it to the pistons. The motor is started by means of a wooden handle fixed to the end of a rope passing round a pulley beneath the dash in such a manner that the driver can haul it up towards him from the seat. Normally the running mechanism is out of engagement with the crank-shaft and is brought into gear with it automatically when starting. The car is built somewhat high, and usually is fitted with solid rubber tyres, being specially intended for all-round work in Scotland. The steering gear provides an exceptionally large range, it being possible to turn round in a comparatively narrow street. Considering the high centre of gravity, the car possesses great stability.

The petrol car has been adapted to commercial purposes, that is, the delivery of goods in town and country. Petrol delivery vans differ from touring cars practically only in the shape of the body, the frame and mechanism being altered but little. So much so is this that there would be little purpose in describing many examples of commercial vehicles, and all that will be done here is to treat the Milnes petrol lurry in detail and one example of alcohol lurry, in both of which the motor and mechanism have been designed with the conditions of their ultimate employment well in mind.

The Milnes lurry is shown in elevation by Fig. 732, and in plan by Fig. 733. The propelling mechanism is suspended from the channel steel main frame, the motor E being mounted towards the front of the frame, and its power being transmitted from its crank, shaft through a friction clutch, C, to the first motion shaft of the change-speed gear enclosed in case G. The second motion shaft of the change-speed gear is connected by jointed rod D to a short shaft carrying a bevel pinion which gears with a bevel wheel mounted on the sleeve of the differential gear H on the divided cross shaft J. Keyed spur pinions at the end of the cross shaft gear with internally toothed rings on the rear road wheels. The cross shaft and the short shaft carrying the bevel pinion are mounted in bearings attached to two longitudinal wooden radius bars, shown in Fig. 732, which are connected by cylindrical bearings on the rear axle and pivoted at their front ends from the longitudinal members of the frame; these bars preserve the necessary radial distance for the shaft D and for the spur wheels K. The motor E has four vertical cylinders whose bodies and heads are cast together in pairs, so that there are no external water joints. The mechanically operated admission and exhaust valves are in separate pockets on opposite sides of the combustion chambers, and the low tension

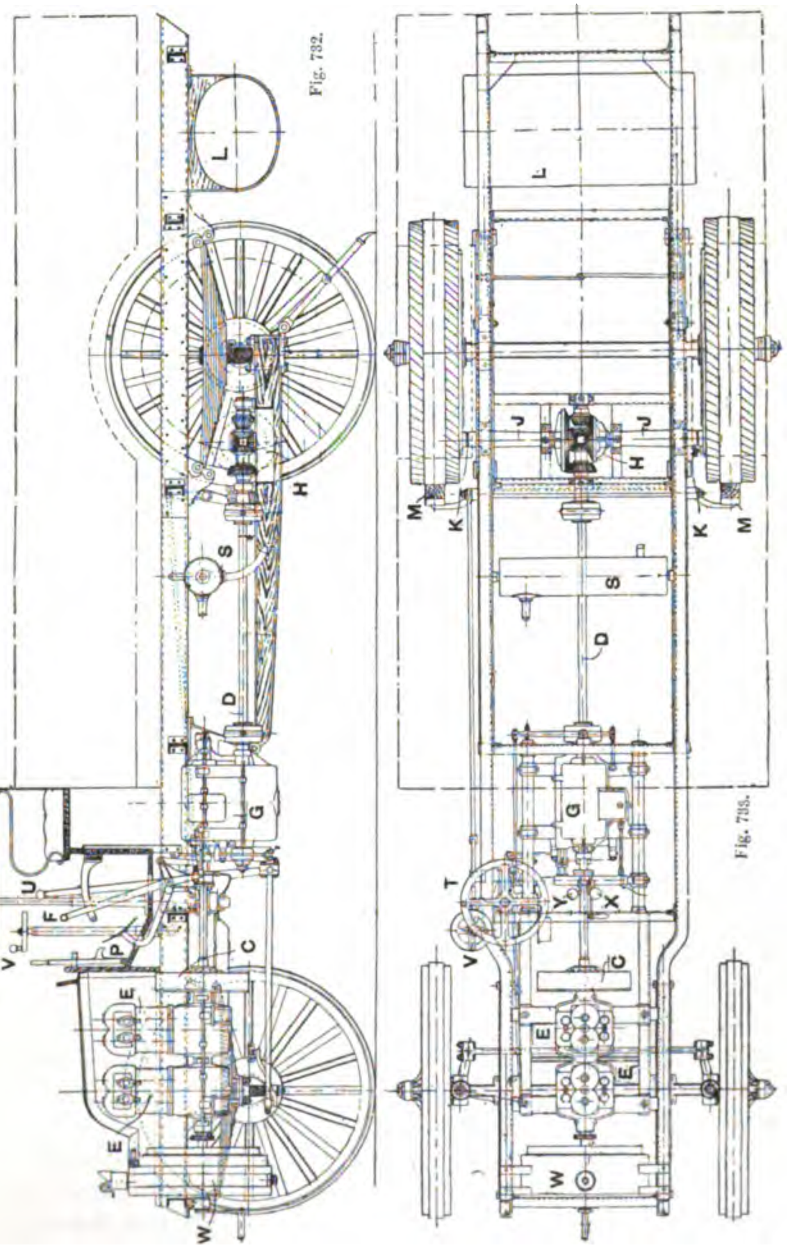


Fig. 732.

Fig. 733.

Figs. 732 and 733.—Elevation and Plan of Milnes Petroleum Lurry.

electric ignition is of the Simms-Bosch rotary type. In order that either petroleum or petrol spirit may be used, there are two float-feed carburetters, one being fed by gravity from the petrol spirit tank behind the driver's seat, and the other by exhaust pressure from the petroleum tank L, suspended below the underframe at the back; the induction tube is exhaust-jacketed for a considerable length, so as to vaporise the heavy oil. The motor is started with spirit and maintained with oil, and to govern it the supply of carburetted mixture can be throttled; X Y show the governor. The exhaust from all four cylinders is taken by a single pipe to the silencer S. For cooling the cylinder jacket water, a combined tank and radiator, W, of the air tube and fan type, is attached to the underframe in front. The metal cone friction clutch is controlled by the pedal P. The change-speed gear, of the sliding spur-wheel type, is arranged on the Cannstatt system, the spur pinions of the four forward speeds being mounted in pairs and controlled by a hand lever U. To obtain a reverse speed, lever F throws in a third pinion between two of the forward gears when these are not engaged. A section of the change-speed gear is shown by Fig. 734, whilst Fig. 735 is a plan and section of the combined bevel and differential gear. The steering is arranged on the Ackermann system, and is controlled by the hand wheel T, there being the usual worm and sector gear. There is a pedal-operated double-acting brake on the countershaft (second-motion shaft), and

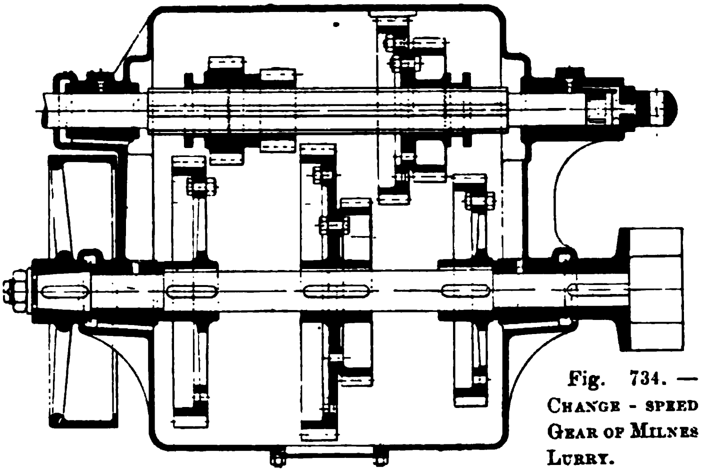


Fig. 734. — Change - speed Gear of Milnes Lorry.

block brakes M, applied through worm gearing from the hand wheel V, act on the tyres of the rear wheels. Details of the countershaft brake are illustrated by Fig. 736. It has been remarked that the motor approaches as near perfection as any heavy oil motor yet employed upon a self-propelled vehicle.

The alcohol-driven lurry of the Société Nancienne is illustrated in front view by Fig. 737, whilst Fig. 738 shows a sectional elevation of the vehicle. The main frame is of channel steel lined with wood, and it supports the Gobron-Brillié two-cylinder motor (p. 245) through a pair of bent girders strongly braced in front. There are three mechanical changes of speed and one reverse, but the ignition is varied with ease, and intermediate speeds are possible. The 32 kg. (70 lb.) fly-wheel transmits power by means of a cone friction clutch to the change-speed gear wheels, whose secondary shaft, by means of gear wheels, drives the differential upon whose periphery works a double-acting brake. A spring pawl adapted to the hand wheel which actuates the shoe brakes prevents slipping of the sprocket upon which the chain operating the shoes is wound. The steering gear is of peculiar design, as illustrated in Fig. 738. The total weight of the lurry is 2·5 tons, and its load is from 3 to 5 tons. Its

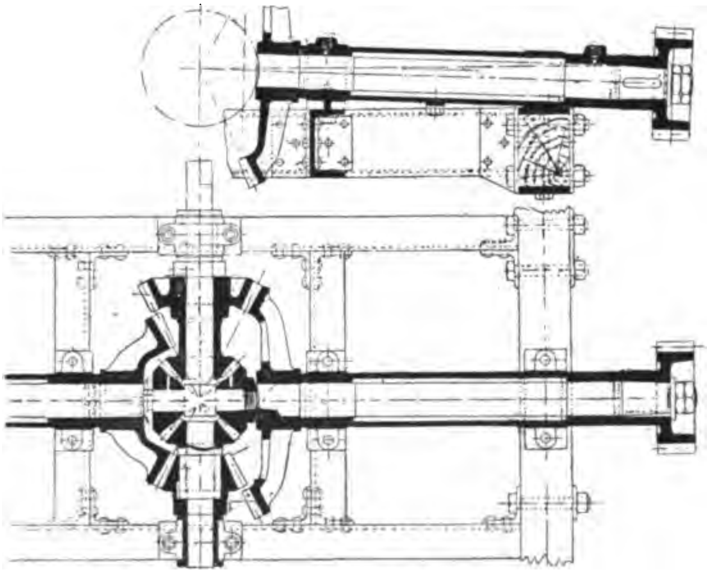


Fig. 735.—Milnes Driving Shaft and Differential Gear.

consumption of alcohol when carrying a load of 3·37 tons at a speed of 9·1 km. (14·6 miles) per hour over bad roads, works out at ·0963 l. per car ton-kilometre, or ·1678 l. per ton-kilometre load (·2728 pt. per car ton-mile, or ·4748 pt. per ton-mile load).

Motor fore-carriages easy to couple to any kind of car would have many advantages; for instance, ordinary cars could be employed and yet remain suitable for horses; the cars would be hauled and not pushed: motor and body easily could be kept separated, and consequently there would be no vibrations. Enthusiasts add that transmission would be simplified, all the weight of the motor would be utilised for adherence, on falling gradients and slippery, wet ground the weight of the fore-carriage would prevent the rear-carriage from rocking, and that, lastly, when stopping suddenly, the front wheels could be locked and the car prevented from swinging round.

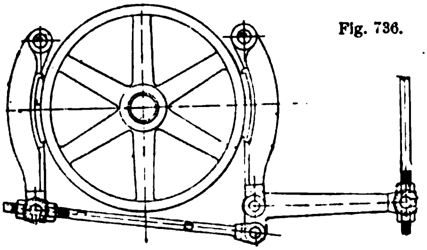


Fig. 736.

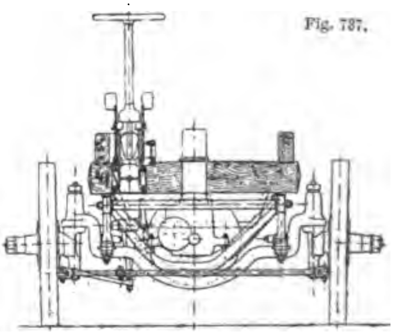


Fig. 737.

Fig. 736.—Milnes Countershaft Brake.

Fig. 737.—Front Elevation of Nancienne Lurry.

But for all these advantages there are but few examples of practicable motor-fore-carriages in actual employment, and there has been but little progress during the past three or four years. It is not thought desirable to more than mention here a few of the many suggested contrivances.

The Prétot fore-carriage, the first of the type, was on view at the Salon du Cycle et de l'Automobile of 1896. All the mechanism, motor and transmission, was enclosed in a box suspended by springs above the axle, and was bathed in oil. The box had a rolling path similar to that of the fore-carriage, which was detached from the car, coupling being accomplished by the ordinary pivot. Changes of speed were obtained by a device described on p. 408, unfortunately of delicate structure and difficult to lubricate. Forward and backward motion were given by a single lever, as were also the rate of speed, the locking of the brake on the differential, and stoppage. It was ingenious, but did not give good work, partly because, to relieve the pivot, the fore springs were subjected to traction strains.

The Riancey fore-carriage (Fig. 739) hauls a rear-carriage. The motor is placed before the only axle of the fore-carriage, and its shaft drives by a bevel gearing a transversal shaft, carrying the speed-changing and reversing gear, and by them the differential shaft upon which the wheels are keyed. The heads of the connecting rods and the gearing dip into oil contained by the water-tight gear case, under which are the petrol spirit tank and the silencer. The accumulators and ignition coil are behind the fore-carriage. This last is coupled to the rear-carriage by means of a socket, around which it turns for steering, and in which it can ascend and descend to constantly keep the four wheels in contact with the ground. There are two brakes.

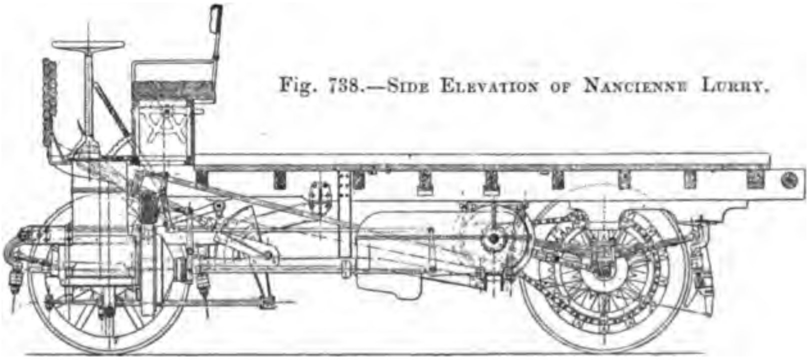


Fig. 738.—Side Elevation of Nancienne Lurry.

Some other systems, which in some cases are only suggestions, may be noted. Those of Amiot-Péneau with its Daniel Augé motor, Ponsard-Ansaloni with a Roser-Mazurier motor, and Doré driven by petrol or electricity may be mentioned merely. The Lockert fore-carriage has belt and friction plate transmission which can be replaced by toothed gear. The Émile Salles fore-carriage has its motor driving a flexible shaft, which communicates motion to the wheels mounted to turn in chapes. The Ringelmann fore-carriage has a steering wheel in front, united to the supporting springs by a triangular frame, which carries the motor, whose movement is transmitted by chains to toothed wheels keyed on the axle. This fifth wheel is found in the Johnson fore-carriage, which, like the petrol-electric cars described in Chapter XX., has a two-cylinder petrol motor, a generating dynamo, an electric motor, and a battery of accumulators, the last-named storing the current when the electric motor does not consume all. The dynamo is run by the petrol motor, and the electric motor and a belt communicate motion to the driving wheels. Finally, the Heilmann four-wheel bogie is a regular tractor which can haul any car coupled to it after removing the fore-carriage. For some months the inventor, Heilmann, employed it to haul a landau, and he has attempted to modify the bulk, weight, and inartistic appearance of the fore-carriage, and to substitute a petrol motor with magnetic coupling for speed-changing for the electric motor previously employed.

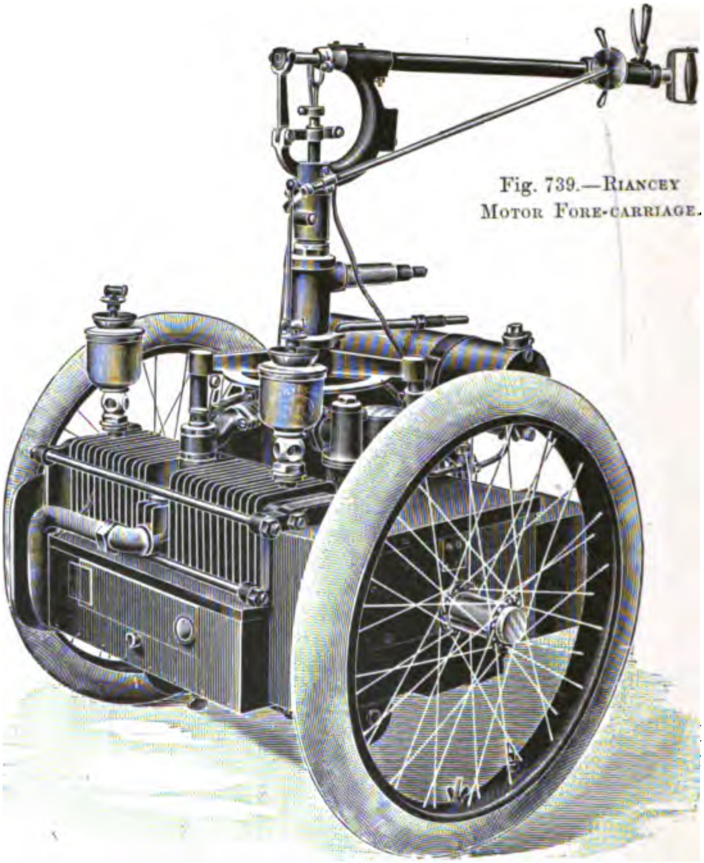


Fig. 739.—Riancey Motor Fore-carriage.

CHAPTER XIX.

ELECTRIC AUTOMOBILE CARRIAGES.

THE plan or general arrangement of an electric car is understood easily. It comprises (1) accumulator cells divided into several batteries usually enclosed by cases, but sometimes grouped in a frame under the car frame; (2) a motor, sometimes keyed on a shaft concentric with the differential shaft carrying the wheels, but more generally it is on a shaft which drives the differential shaft by gearing, this gearing working, by endless chains, the loose wheels on the axle; very rarely mechanical speed-changing devices are employed; (3) a controller or coupler to distribute current and make couplings suitable to the momentary requirements in driving the car. Also there are: a rheostat with graduated resistances; ampèremeter mounted in tension on the circuit; a voltmeter placed on a shunt, sometimes an energy recorder which shows the amount contained in the accumulators at any moment; two fusible cut-outs placed on the wires running from the accumulators at a point before their passage into the mechanism; and there is an interrupter, a kind of key which the driver takes away when he leaves the car.

The first electrically driven road vehicles appeared in 1881, when Raffard drove a tricycle with an electric motor of 7 kgm. (50·63 ft.-lb.) power, fed by twelve Faure small accumulator cells; the vehicle weighed only 80 kg. (176 lb.). An omnibus owned by the Compagnie Générale des Omnibus of Paris he transformed for running on rails and ordinary roads. Pouchain's six-seat phaeton (1893) had four aluminium boxes lined with celluloid, each containing thirteen Dujardin accumulator cells having a total weight of 500 kg. (1,100 lb.), about one-third of the weight of the entire car, which was driven by a Rechniewski motor. Bogard's two-seat dogcart, weighing, when loaded, 2,300 kg. (5,060 lb.), was fitted much the same. In 1896 Darracq exhibited at the Paris Salon du Cycle a very interesting coupé.

The Morris and Salom electrobat, the first electric car that ever ran in America (August 31st, 1894), was a large dogcart with six places, mounted on wooden wheels, with iron tyres and ball bearings.

As a rule, the electric voiturette does not seem to commend itself, owing to the difficulty in fixing the accumulator and its slight radius of action. The steering driving fore-carriage, carrying a battery and a motor, was still less commendable, and does not promise much. Perhaps on account of the facilities of new supplies, and for other reasons, the electric voiturette will be more serviceable in America.

Many constructors, especially modern ones, recommend the use of double motors for heavy cars, and this makes it possible to dispense with differential, toothed gear, etc. Recuperation, which has been abandoned in the case of tramcars, has been found highly suitable for cars, whilst the electric brakes generally fitted have the advantage over mechanical brakes of locking the two wheels more evenly and thus lessening skidding. The actual suspension by half-nippers in front and nippers in the rear can be replaced profitably by nippers in front and crooked nippers with clicks in the rear. Steering with a one-pivot fore-carriage gives very good results, and greater solidity would be given if the pivot of many existing cars were lowered a little.

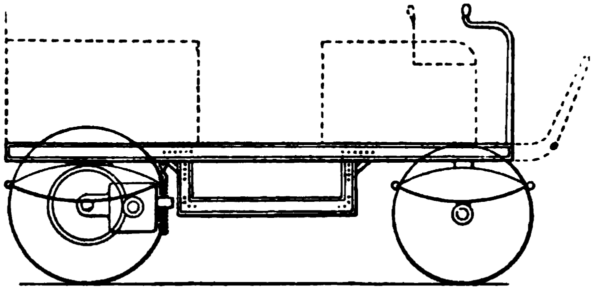


Fig. 740.—Aultman Electric Lurry.

The main frames of electric cars may receive attention.

The Aultman two-ton electric lurry has the rectangular channel steel frame shown in Fig. 740, and the battery is supported in a receptacle under the platform. The two electric motors are geared to the back wheels as in Fig. 316, p. 320.

Frames such as are illustrated by Figs. 741 to 743 have one particular object; they form a "perch pole" or "reach," coupling the back to the front axle, so that the two are propelled together, and the power has not to be transmitted indirectly through the car springs as it has to be in the type illustrated by Fig. 740.

The Scheele sectional steel frame (Fig. 741) carries two electric motors geared as illustrated to the back wheels.

The chassis of the Joel voiturette is shown in plan and end view by Figs. 742 and 743. The steel tube frame carries two electric motors which drive the rear road wheels by means of bicycle chains. The half-elliptical suspension spring in front is placed horizontally, and is pivoted to the centre of the front axle; whilst at the back a similar spring is in a vertical position, and is secured to the centre of the rear axle; thus there is provision for resilient movement both horizontally and vertically. The chains are adjustable, and are kept in proper tension by the front springs, whilst the back spring takes up the strain of starting the car. The batteries are under the car seats. Joel motors are described on pp. 324 to 327.

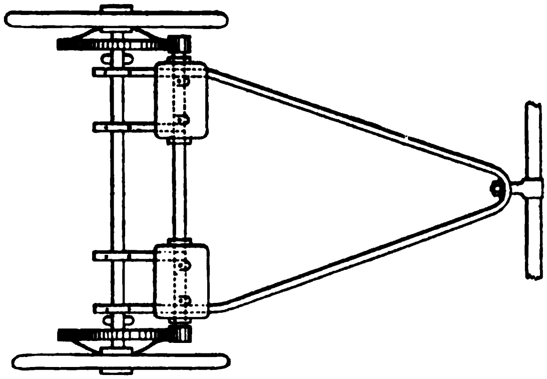


Fig. 741.—Scheele Electric Car Frame.

The de Dion-Bouton electric car employs a large, slow-speed four-pole motor, mounted in the position occupied by the change-speed gear in those petrol cars which drive through a longitudinal shaft. This enables very simple arrangement of the parts, but is to a certain extent at the expense of weight, since the speed reduction, owing to the method of mounting, is confined within certain limits, and this involves a slow speed, and consequently a comparatively heavy motor. This, however, is not a serious addition to the total weight of the car. The motor has a speed of 800 revolutions per minute, and it drives direct on the live rear axle differential by means of a short longitudinal shaft and bevel gearing. The motor is completely enclosed in an aluminium casing, and there are inspection apertures on the commutator side near the brush holders. The brushes are normal to the commutator, as usual with this type of motor, and the armature is drum-wound with a tooth core. The controller is light and compact, weighing only 8·35 kg. (18·4 lb.), and is mounted underneath the front of the car in an aluminium frame, being fixed in its different positions by a spring pawl. The aluminium-bronze contact springs are pressed against the contact pieces on the drum by steel springs, but in each case the current is carried by special copper connections. The movements of the controller cylinder are effected by chain wheel transmission, which is operated by a hand wheel mounted on the steering pillar. The controller is arranged to give four speeds by series and parallel grouping of the field windings and the battery. The reverse is effected by a special switch. A series of resistances can be successively thrown into circuit by means of a pedal, and give speeds between those obtained by the controller; the extreme position of this

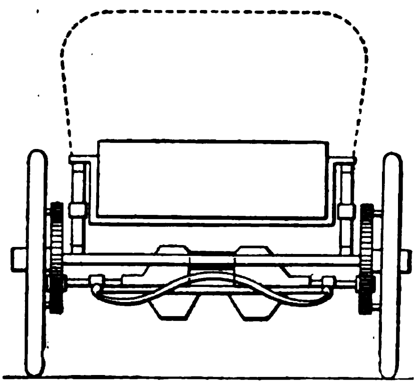


Fig. 742.—Rear View of Joel Voiturette.

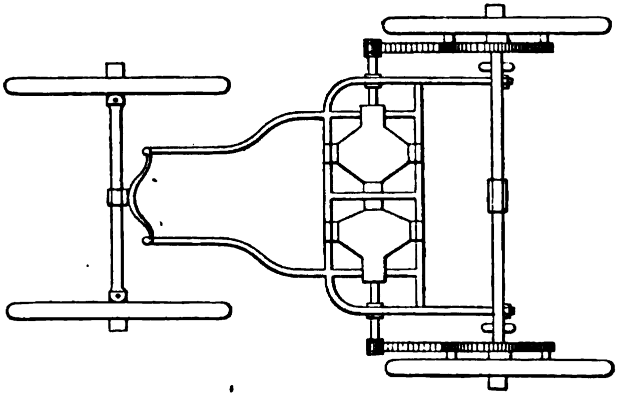


Fig. 743.—Plan of Joel Voiturette Chassis.

pedal interrupts the circuit and applies the rear wheel brakes. The tubular frame is adapted for almost any type of body. The steering is of irreversible pattern, and the wheels are provided with 90 mm. (3·54 in.) tyres with thickened threads. It is not unnatural that there are considerable traces of petrol car practice in the design and construction of the vehicle.

An old-type Jenatzy car is represented by Fig. 744. The forty-four elements B_{21} are in two boxes front and rear of the body. There is a series motor with two poles and a drum secondary coil driving the differential shaft, which, by chains and pinions, moves the rear wheel. The speed can be varied (1) by parallel connections of the two batteries (for slow speed), or series connections (for full speed), (2) by inserting variable resistances in the circuit, (3) by placing a pair of toothed wheels in the transmission, reducing the speeds given by the preceding devices in the ratio of 100 to 67. Combination of these three means gives a varied scale of speeds. To simplify the controller, it is not employed either for recuperation or for braking. A handle serves to place the motor in the circuit and insert the resistances; moved in the opposite direction, it gives reverse motion at the same rate of speed as forward. The car is very simple. The driver has before him the coupler; on the left the mechanical speed-changing lever; on the right the steering lever; and at his feet the pedal of the band brake mounted on the differential shaft. The shoes can be locked on the rear pneumatic tyres by means of a hand crank. Hospitalier remarks that this handle ought also to switch off the current, so that the car cannot be set in motion as long as the brakes are locked.

In a Jenatzy cab and delivery car there are two motors, each of which drives a rear wheel by gearing; change-speed gear and the differential are therefore suppressed. The single controller is replaced by a rheostat with handle, placed in the general circuit and three buttons for connecting, in series or multiple circuit, the two halves of the battery, the two primaries, and two secondaries, according to the combinations in the table given at the top of the next page. The lever for working the rheostat has the ten different positions shown.

Hospitalier fears that, in difficult cases, working of the rheostat and button may cause errors impossible with an ordinary controller. The torpedo car—the "Jamais Contente"—with which Jenatzy won the

JENATZY CONTROLLER CONNECTIONS.

Speeds.	Accumulators.	Field Magnets of each Motor.	Motors.
1	Multiple	Series	Series
2	—	Multiple	—
3	Series	Series	—
4	—	Multiple	—
5	—	Series	Multiple
6	—	Multiple	—

kilometer record in 1899 had the form of a shell with a double point. It was mounted on four wheels, each 65 cm. (25·6 in.) in diameter; the two rear wheels were interdependent with the secondary coil of a motor. At a speed of nearly 106 km. (65·8 miles) per hour which was realised during a minute, the secondary coils turned at the rate of 900 revolutions per minute. Considering the power expended at starting (250 ampères at 200 volts), it would have been difficult to have this power utilised by a motor turning quicker, without complicating transmission and decreasing efficiency.

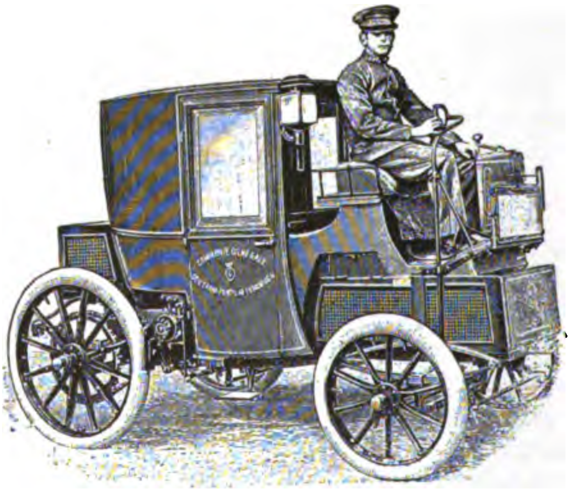


Fig. 744.—Jenatzy Electric Coupé.

The British Electromobile Company's electric car, the chassis of which is illustrated in Fig. 745, was introduced at the beginning of 1902. It has two electric motors, A, mounted on the rear axle, each driving independently one of the rear wheels by spur gearing. Instead of being mounted on a false axle which turns with the wheel, as in the Kriéger system, the motors are mounted on the spring suspension principle on the fixed rear axle. To the framing of the car on either side is secured a bracket, B, which bears the spiral spring C, attached to the top of the motor, the thrust of the motor when driving being thus spring-cushioned on to B. The spur gearing is completely enclosed inside casing D, this casing being in one piece with the brake drums E secured to the wheel spokes. An additional external bearing in the gear casing at F is supplied for the pinion shaft. The controller G is mounted with a slight rake, as illustrated, to agree with the inclination of the steering pillar H. The steering is by worm gearing, and is illustrated sufficiently at J, whilst K shows the method of applying the brake to the rear wheel by the pedal L, shown on the far side of the controller. A form of a quick make-and-break action, similar in principle to the quick make-and-break employed in switches for electric lighting, causes the controller to snap rapidly from one position to another, thereby reducing to a minimum any evils that may result from sparking. The contact springs are of phosphor-bronze with copper contact pieces. The connections for recuperation are entirely outside the main controller, and are made by special pedals, not shown in Fig. 745, the arrangements being that when the driver desires to recuperate he presses down one of these pedals, putting the controller in the position which arranges the combination which would ordinarily produce either the first or second speed forward. This then automatically gives the

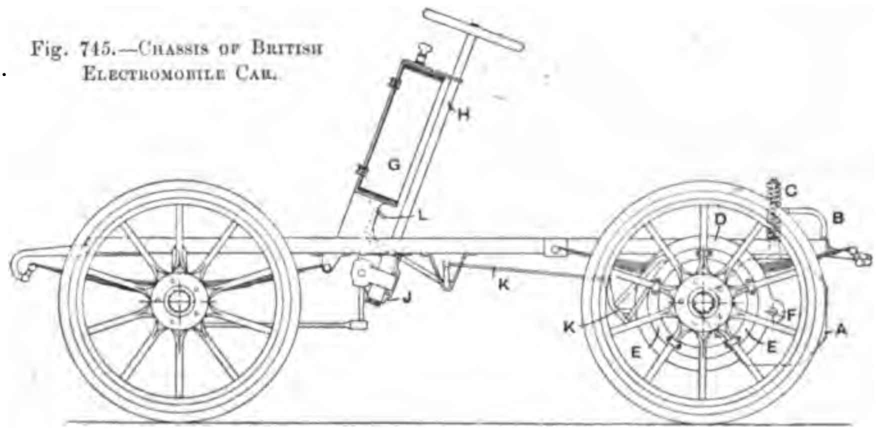


Fig. 745.—Chassis of British Electromobile Car.

required degree of recuperation. The second foot pedal puts in a series of resistances which can be cut out gradually by movement of the pedal, and these resistances can be used either to modify the speed when running forward or to modify recuperation when recuperation is being employed. The controller is contained in a water-tight aluminium case, and being quite independent of the steering pillar, the whole of the circumference of the controller cylinder can be utilised. There are eight positions for the handle, and each position is at an angle of 45° with the next. These positions give one reverse speed, electric brake, stop, and five forward speeds. The cars have Leitner batteries.

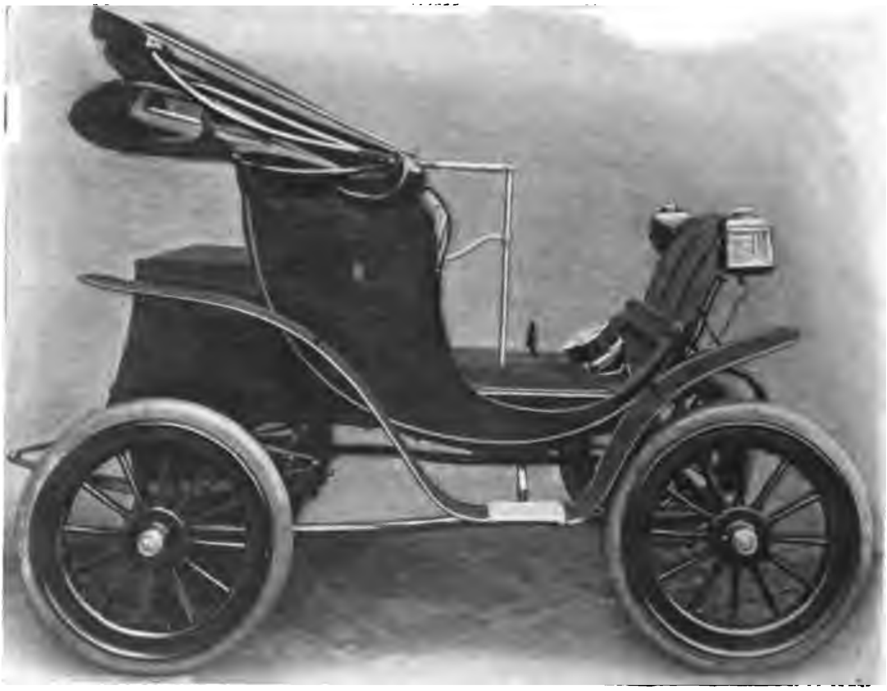


Fig. 746.—City and Suburban Electric Victoria.

The City and Suburban electric cars have been running successfully for a number of years; they are made in many styles, from the light and cheap runabout to the graceful but substantial Victoria shown by Fig. 746, this figure being a reproduction of a photograph of a car made for Queen Alexandra. Compactness is a characteristic of cars of this make. The system of control is described on p. 747.

The Electromobile vehicles now differ from one another only in the bodies attached, and all the mechanism, etc., is on the Contal system and is standardised. The landaulette is a new type of vehicle specially designed for London use. The light rectangular frame is of channel steel, with two cross struts of similar material near the front and the rear. A single series-wound Contal motor is mounted, with spring suspension about the rear axle, and drives through completely enclosed double-reduction gearing on to the differential of the live rear axle. The wheels are of the artillery type, and the rear ones have expanding brakes operated by a pedal, and consisting of two pivoted blocks mounted inside a ring and expanded by means of a double toggle joint operating against the action of a powerful spiral spring. The controller is mounted horizontally in front of the chassis, and is operated by a hand lever immediately under the steering wheel, which actuates it by means of a sleeve passing down the inclined steering pillar, and carrying a quadrant at its lower end, which engages with a spur wheel on the end of the controller. The various positions of the controller give five speeds and a reverse by different groupings of the motor fields, and arranging resistances in connection with them. Two positions of the controller also provide an electric braking effect, in the first of which the armature circuits are closed through a resistance, and in the second of which they are short circuited altogether—current in that case being separately provided for the fields. A quick brake cut-out is operated by the brake pedal, so that the rear wheel brakes cannot be applied without first throwing the motor out of action. The battery is slung exactly in the middle of the frame, and mounted underneath it so as to render the batteries readily interchangeable ; the battery box is carried by four lugs, through which project four stout horizontal taper pins, when it is in position. When a battery is to be removed its weight is taken by a lift or jacks, the taper pins are screwed back by winches, and the battery box can be then lowered, the carriage wheeled away, and a fresh battery attached to it. The battery box itself contains an adjustment by which all the cells can be tightened up in position, and this, of course, can be relaxed for removing them for inspection. When the battery box is to be dismounted, connection between it and the car can be severed completely by a flexible connection and a concentric plug. This plug is removed for charging and another one inserted. This method completely obviates the possibility of the car being started whilst in course of charging, as sometimes may happen when a car is charged through the controller. The battery consists of forty-four Contal cells of 135 nominal ampère hours, though said to give 150 ampère hours in practice. Each cell contains twenty-one plates of the mechanically pasted type, and weighs 13·1 kg. (28·8 lb.) complete.

The Contal electric motor, employed on Electromobile vehicles, was designed by Contal and P. Gasnier; its novel disposition of the windings permits of reducing the magnetic leakage to a minimum without any magnetic joints, the motor working sparklessly with fixed brushes, with a relatively small amount of copper, and in a small space. Its speed is 1,800 revolutions per minute. The weight is 12·5 kg. (27·5 lb.) per B. H. P.; its efficiency, according to tests made by the Laboratoire Central d'Electricité, varies between 80 and 87 per cent. Spiral springs acting as buffers are placed between the motor and the lower part of the underframe. The general method of mounting the motor is rather peculiar. It runs upon a hollow shaft, through the centre of which runs the driving shaft connected to the driving wheels and the compensating gear, the latter being driven from the motor by a kind of back centre reduction gear. The following speeds are available on the Contal system :—

–1	Backwards	Armature windings in series and reversed	Field winding in series	Resistance in circuit
000	Electric Brake	In parallel and reversed	In parallel	Do., out
00	,,	,, ,,	,,	Do., in
0	Stop	Cut off	Cut off	Cut off
1	8 km. per hour	In series	In series	In circuit
2	11 km. ,,	,,	,,	Off
3	16 km. ,,	,,	In parallel	,,
4	21 km. ,,	In parallel	,,	,,
5	26 km. ,,	,,	Do., with shunt	,,

The Vehicle Equipment Company's electric brougham has downwardly projecting vertical guides fixed to the main frame at each side, so that the front and rear axles are free to slide in them against the action of compression springs. The axles have square boxes which fit in the guides, the arrangement resembling the railway practice of employing horn plates. There are double-elliptic side springs at the rear between the frame and the axle, outside the guides ; two semi-elliptic transverse springs forming an X serve the same purpose in front, the ends of the upper spring being secured to pins passing across the guides, and the ends of the lower spring being articulated to the boxes on the axle. Two separate motors are mounted about a stationary rear axle, and drive by raw hide pinions on to spur wheels attached to the spokes of the driving wheels. The driver's seat is perched up behind as in a hansom, and steering is by tiller. The controller is under the seat, and gives four forward speeds and two reverse. The battery is slung under the centre of the frame in a cradle, so that the battery can be slid out at either side.

Jeantaud cars belong to two distinct types, a laudau with rear driving axle and coupé with steering motor fore-carriage. The drojki, a pleasure carriage with a single seat in front, was of a very similar type to the first. In Jeantaud carriages having rear driving axles the accumulators (two groups of twenty-two cells with fifteen plates) are carried in the front and rear boxes, but in the cab they are placed in a box on the fore-axle, thus equilibrating the driver's weight.

The motor has its secondary coil on a drum, and the primary, with two poles, has a double winding, one

CONTROLLER FOR JEANTAUD CARS WITH REAR DRIVING AXLES.

Positions of Controller.	Condition of Car.	Accumulators.	Excitation Series.	Excitation Shunt.	Armature.	Rheostat.
1	Reversing	Parallel	In Circuit	In Circuit	In Circuit	In Circuit
0	Brake-locking	Open Series	In Circuit and on secondary wire	Out of Circuit	In Circuit and reversed	In Circuit for locking brake
1	Slow Speed	Parallel	In Circuit	In Circuit	In Circuit	*In Circuit
2	Average Speed	Series	—	—	—	Out of Circuit
3	Increased Speed	—	In Circuit shunted on two resistances	—	—	—
4	Full Speed	—	In Circuit shunted on one resistance	—	—	—

* Mechanical locking does not allow the coupler to pass from position 1 to position 2, except the starting resistance controlled by a pedal under the driver's foot has been brought into the circuit previously.

series and the other shunt. It transmits power, by toothed wheel, to an intermediary shaft which carries the differential and by endless chains drives the rear wheel. The table below and the one on p. 703 give the different work of the coupler (*see* also p. 337).

CONTROLLER FOR JEANTAUD CARS WITH STEERING MOTOR FORE-CARRIAGE.

Positions of Controller.	Working.	Batteries.	Field Magnets Series.	Field Magnets Shunt.	Armature.
0	Stoppage	Series and insulated	Open	Open	In short circuit
1	Slow speed	Parallel	In circuit	In circuit	In circuit
2	Average speed	—	In short circuit	—	—
3	Accelerated speed	Series	In circuit	—	—
4	Full speed	—	In short circuit	—	—

Independently of the coupler, the car is controlled by (1) a horizontal hand steering wheel, acting on the wheels of the fore-steering axle, (2) by a lever for the rope brake, which breaks the circuit and acts on the rear wheels in both directions, (3) by a pedal controlling the starting rheostat, and exceptionally (4) by a crank working a tyre brake.

The arrangement of the vehicle with steering motor fore-carriage is illustrated by Figs. 428 and 429, p. 424, the mechanism being explained on p. 425. There are fifty B_{17} elements; motors have double winding and various couplings to obtain four speeds and stoppage, as explained in following table. Rear motion is obtained at all speeds by a special reverser.

Kriéger general cars are more complicated than the Jeantaud cars.

The coupé, the vis-à-vis, and the corridor cab differ only in the body. The frame, supported by wooden wheels and made of wood and steel itself, is straight, and can, by aid of springs, carry any kind of body. It also has two boxes, one in front and the other in the rear, each of which contains a battery, inspected and changed with great facility. The table at the top of p. 705 shows the connections on an old type Kriéger car; for the new system, *see* p. 337. Twenty-two elements B_{17}, always coupled in series, compose each of these batteries, and feed two four-pole motors, having four excitation coils, two with thick wire in series, and two with thin wire in multiple circuit, the drum secondary coil performing 2,000 to 2,600

CONTROLLER FOR KRIÉGER CARS.

Positions of Controller.		Two Batteries.	Excitations.	Two Armatures.
1	Reverse motion	Multiple	Shunt and series	Series and reversed
00	Working brake without recuperation	—	Shunt	Short circuit
0	Stoppage	Series	Open	Open
1	Starting	Shunted	Shunt and series	Series connection
2	Second speed	—	Series	—
3	Third speed	Series	Shunt and series	—
4	Fourth speed	—	Series	—
5	Fifth speed	—	Shunt and series	Multiple
6	Sixth speed	—	Series	—

revolutions per minute. Each is mounted on a pivot of the fore-axle, which is both driving and steering, and communicates motion, by a spiral pinion, to a toothed wheel mounted on a corresponding wheel. The ratio of these gearings is 1 to 17 or even 18, probably the greatest ever employed, and it may be asked whether it is not a cause of excessive strain and rapid wear for the pinion. There are six feeds, as stated in the above table. The driver has at command, besides the coupler, a hand steering wheel (replaced in later cars by a steering bar with vertical handles), a plate compressor brake on the rear wheels and controlled by a pedal, and a recuperator button also worked by the foot. Kriéger's new coupler (p. 337) is of reduced dimensions, and is provided with two new positions; the two electric motors are horizontal and suspended.

The Mildé electric car is known in a variety of styles. The electric differential type motor, described on p. 323, is enclosed in a case which protects it from dirt, but its parts are easily accessible and the entire motor can be taken apart very quickly. The battery of Heinz accumulator cells employed weighs 460 kg. (1,014 lb.); there are 42 elements whose output is 116 ampère hours at a five hours discharge rate. Without battery, a Mildé landaulet or coupé with two places weighs about 850 kg. (1,874 lb.). Power is transmitted by two pinions fixed on the ends of the two armature shafts, these gearing directly with toothed bevelled rings secured to the back wheels. The controller is arranged in the longitudinal axis of the car, the cylinder carrying the coupling contacts being easily accessible; it is operated by a little handle which falls into notches corresponding with the different combinations giving the seven or nine forward speeds varying from 3 to 30 km. (1·86 to 18·6 miles) per hour, the two or three reverse speeds, and the one or two positions in which recuperation is obtained. The car is well supplied with brakes; besides the recuperating and braking effect to be obtained on long descents by employing the motor as a dynamo-generator, there are expanding brakes acting either forwards or backwards inside the toothed bevelled rings on the rear wheel naves, or, instead, there are band brakes acting on their circumferences. The main frame is of channel steel, curved or straight, and is both light and strong; it carries the whole of the mechanism. The expenditure of energy in propelling the car is said to work out at 55 watt hours per ton-km. (88·7 watt hours per ton-mile).

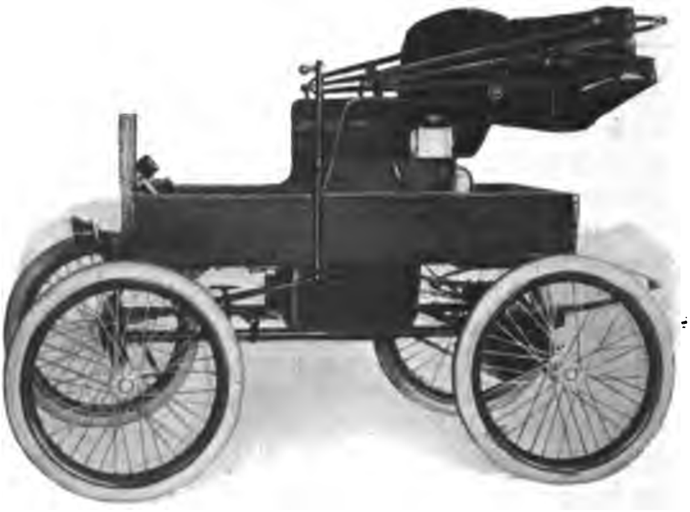


Fig. 747.—Baker Electric Runabout

The Baker electric runabout, Fig. 747, has a frame resembling that of many American steam cars. A four-pole compound-wound motor is mounted centrally, and drives by double reduction on to an open differential on the rear live axle; the motor drives a short countershaft by spur gearing, and this countershaft carries a sprocket wheel from which the transmission to the differential is by a single chain. The controller is mounted under the seat on the right-hand side, and is operated by a side lever. Two brakes are fitted, one on the motor shaft and one on the differential; the steering is of the tiller type. The different speeds are obtained by introducing resistances into the field windings. The battery consists of twelve 70 ampère-hour Exide cells situated under the seat. The connections between the cells are permanent, all being in series.

The Baker runabout steel tubular frame (Figs. 748 and 749) is strong but light, and it supports the motors and batteries independently of the car body; both frame and wheels approximate closely to modern bicycle construction.

A Baker electric racing car, which met with an accident in the Staten Island speed trials, May 31st, 1902, the car running amok through the crowd, killing two persons and badly injuring several others, was made somewhat on the lines of Jenatzy's "Jamais Contente" (p. 697). It had an angle iron framework, nearly straight between the wheels, and bending off at an angle fore and aft with straight ends. It was supported in front on transverse leaf springs, and at the back on longitudinal leaf springs. The motor, built by the Elwell Parker Company, of Cleveland, normally developed 7-h.p., but had a stated output of 12-h.p., and was mounted between the rear axle and the centre of the car, being fitted in a metal frame. A pair of 1 in. pitch chains transmitted the power from each end of the armature shaft to the differential gear in the centre of the live rear axle. The two large sprockets were about 30·48 cm. (12 in.) in diameter, and had internal spring drives in order to cushion any shocks and avoid breakage of the chains. Two band

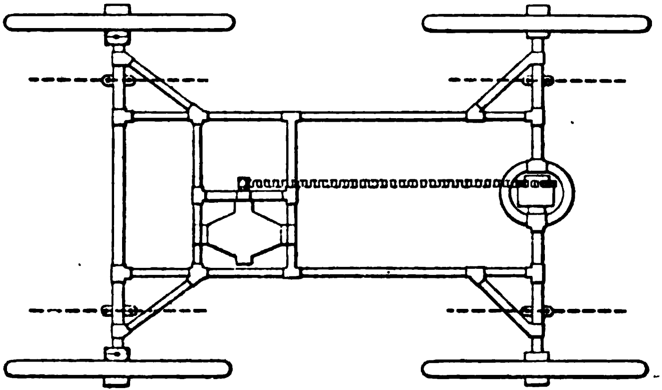


Fig. 748.—Plan of Baker Chassis.

brakes were fitted just inside of the sprockets, these being simultaneously operated through wire cables passing to the brake lever. The differential gear was enclosed, and the whole live rear axle carried in a substantial casting. The accumulators, forty Gould cells fitted in ebonite boxes, were distributed over the machine, eleven behind the rear axle, four between it and the motor, fifteen between the motor and the driver's seat, and the remaining ten in front. The peculiar steering gear is represented by Fig. 750. The inclined pillar A was operated by a 25·4 cm. (10 in.) wheel, B, and its lower end was connected by ·47 cm. (·187 in.) steel wire cables, C, round a 7·62 cm. (3 in.) steel drum, D. Coiled springs are shown at E. There were seats for two drivers, and the entire machine was enclosed in a shell, covered with black cloth. The floor, above the level of which all batteries and machinery were fixed, was little more than 15·24 cm. (6 in.) from the ground, and the wire spoke wheels had wooden rims, were about 91·4 cm. (3 ft.) in diameter, and were covered with oilskin. Palmer tyres were fitted, and the wheel base was about 1·83 m. (6 ft.). The total weight of the machine was about 1,360 kg. (3,000 lb.), and its overall length about 5·48 m. (18 ft.). The drivers' seats were arranged so that a strap passed over their knees keeping them down ; and mica windows were fitted to act as shields for their eyes.

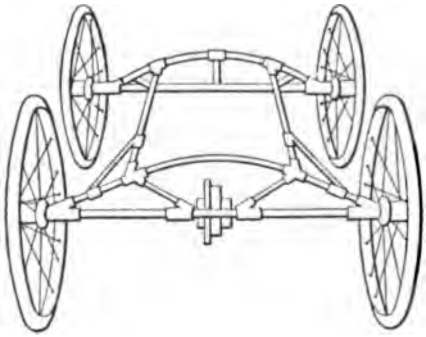


Fig. 749.—END VIEW OF BAKER FRAME.

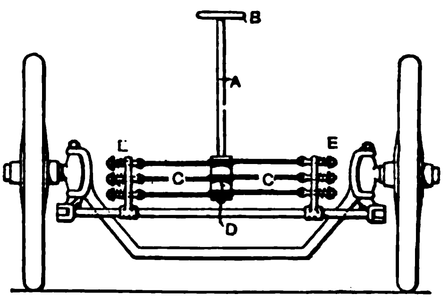


Fig. 750.—BAKER RACING CAR STEERING GEAR.

Waverley electric cars, introduced this year into England, are made in many designs, two representative ones being shown by Figs. 751 and 752. Their distinguishing features are : the type of motor (described in detail on pp. 328 to 330), the method of suspension, the construction of the rear live axle driven through helical gearing by the motor, and the controlling switches which regulate speed, direction, and the electrical brake. Steering is by tiller, in whose handle is a push-button which, when pressed, sounds an electric gong under the car. There is a speed regulation lever beside the driver, and it has three positions forward of the neutral notch, whilst when forced backward against the action of a spring it produces the electric braking effect. A reversing lever projects forward beneath the drivers seat (a safety plug and socket are fixed beneath the lever), a pedal applies the side brakes for ordinary use, and a second pedal an emergency band brake on the motor shaft. On the footboard, and lighted electrically at night, is a combined ammeter and voltmeter. The main controller drum under the driver's seat is connected with the hand lever through a toothed quadrant and pinion ; as the drum rotates it is held in any of its working positions by a spring catch

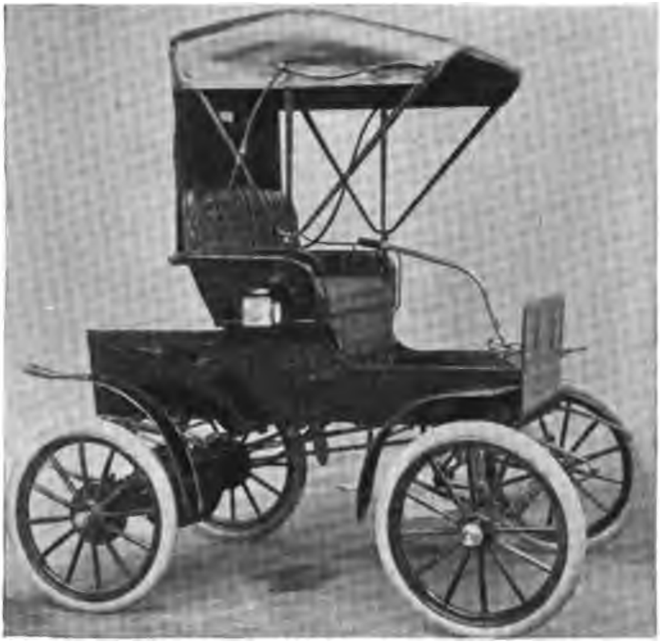


Fig. 751.—WAVERLEY ELECTRIC CAR.

engaging with a cam plate fixed to the drum. Wires connect the controller with the batteries, themselves connected in series and with the motor. A single-motor car has a battery of twenty-four Exide cells, each containing nine plates, the approximate capacity being 110 ampère hours at a discharge rate of 30 ampères per hour (a larger car has forty cells and two motors, all identical with those in the smaller car). The battery is contained in three separate cases, in which are holes for the attachment of temporary handles.

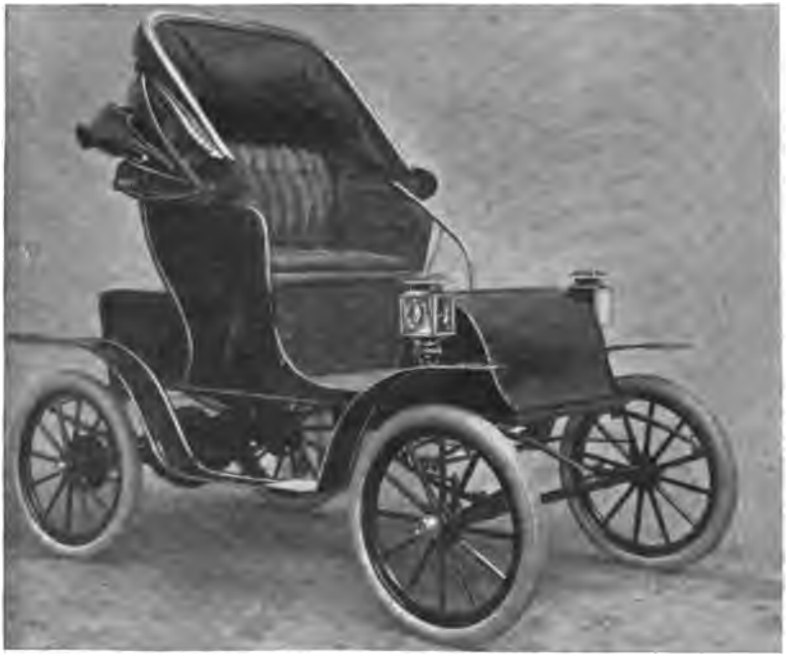


Fig. 752.—Waverley Electric Car.

The main frame of the Waverley car is of wood, stiffened with channel steel cross members, and supported upon full elliptic side springs above both of the axles; a transverse leaf spring carried in a cross channel connects the forward ends of the rear springs together through shackles. The transverse spring is an important detail; it is fixed at its centre and allows the back axle to rock over a certain distance in the one direction or the other, according to the drive of the motor, this action being very apparent when starting the car in either direction. The rear live axle may be regarded as being formed of three substantial tubes, converging from its ends and connected together by the case of the bevel wheel differential gear; it runs on ball bearings and in an oil bath. The front wheels are mounted in ball bearings on the tubular axle though the steering heads turn in plain bearings, a ball thrust bearing taking the weight of the car upon them. The motor, already illustrated and described in detail, is bolted by a flanged coupling to the casing surrounding the differential gear. A driving pinion on the motor shaft meshes with the gear wheel on the differential shell and is completely enclosed, but the motor shaft projects so as to carry a brake drum.

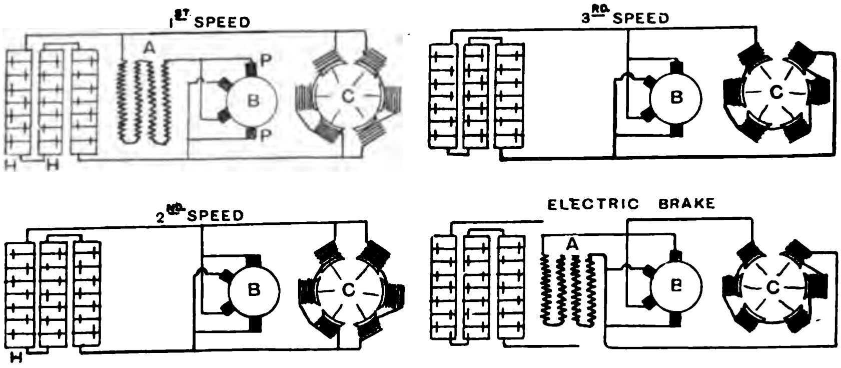


Fig. 753. Waverley Controller Connections.

Charging plugs on each side of the car enable the cells to be recharged without removal.

With regard to the functions of the Waverley controller, Fig. 753 shows, in the order here given, the electrical connections for obtaining the first, second, and third speeds and for applying the electric brake, whilst the complete electrical connections on the car are shown by Fig. 754. The motors are shunt-wound, and the controller is arranged so that when the hand lever is put in its first driving position the current passes through a resistance, A, to the armature B, and through the two sets of field magnet windings in parallel (C shows the field coils). When the lever is moved to its next notch forward, the same connections are retained, but the resistance in the armature circuit is cut out, thus making the motor an ordinary direct-connected shunt machine with a very strong field.

In its third position, the controller places all the field magnet windings in series with one another, and these are connected up across the battery terminals in parallel with the armature. In this case, therefore, a direct-connected shunt-wound motor is in use, and the weakened field gives the necessary increase of speed. When the hand lever is pushed backward from its neutral position, in which it only established the necessary connection for recharging through the ammeter, a braking effect is produced by employing the motor as a dynamo, and connecting its terminals across the resistance coils A. All the various connections made by the controller are shown diagrammatically in Fig. 753. The reversing switch makes connections just the same as in ordinary electric practice. In the next illustration, Fig. 754, D is the plug switch, E the ammeter shunt, F the switch, G the floor push, H the battery terminals, J the steering handle containing the push button, K the charging switches, L the combined ammeter and voltmeter, M the footboard meter lamp, N the side lamps, and O a bell.

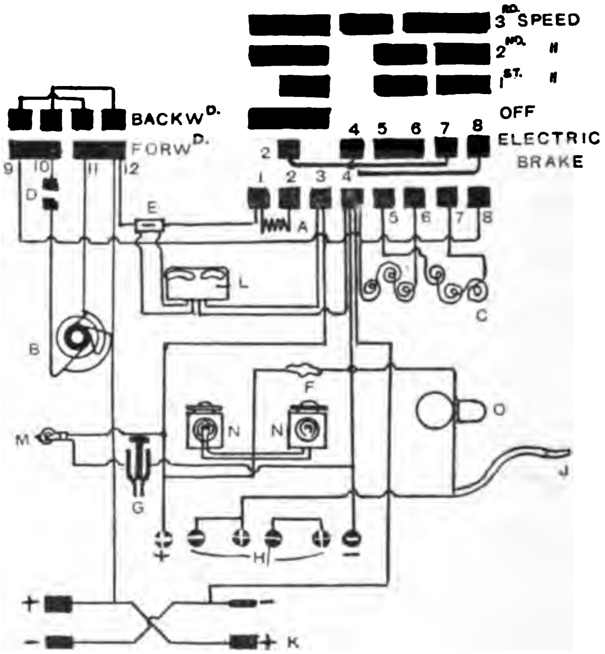


Fig. 754.—Electric Connections on Waverley Car.

In Fig. 753, A is the resistance, H the battery, C the field magnet windings, P the brushes, and B the armature.

Waverley cars with two motors have a battery of forty cells connected in series. The controller places the two motors in series with one another, and speed changing is much the same as in the smaller car. There is no band brake on the motor shaft, the side brakes being found ample in conjunction with the electrical braking effect.

The car of the Compagnie Française des Voitures Automobiles (Fig. 755), with a body suspended on four springs, itself supported, as usual, by springs, has forty-four Faure-King accumulators, which are connected in series, and actuate a Lundell motor with two brushes; this, without interposition of any resistance during working, enables speeds of 4 km. to 18 km. (2·48 miles to 11·1 miles) per hour to be obtained. Transmission to the differential shaft is by toothed gear with leather pinion, and wheels and Renolds chain.

CONTROLLER OF THE COMPAGNIE FRANÇAISE DES VOITURES ELECTROMOBILES.

Positions of Controller.	Working.	Field Magnets.	Armature.	Resistance.	Accumulators.
3	Reverse Motion	In Circuit	Reversed Circuit	In Circuit	In Circuit
000	Second Brake	In Circuit on motor	—	Out of Circuit	Out of Circuit
00	First Brake	—	—	In Circuit on motor	—
0	Stoppage	Open Circuit	Open Circuit	Out of Circuit	Open
1	Starting	Series	Series	In Circuit	In Circuit
2	5 km. per hour	—	—	Out of Circuit	—
3	11 km. "	—	Multiple	—	—
4	14·5 km. "	Multiple Circuit	—	—	—

The above table shows the working of the controller; by pushing the handle more or less forward a gradual speed is obtained; by bringing it backwards the brake is locked, the car stopped and reversed. Steering is obtained by a fore-carriage with a single pivot moving by aid of a toothed wheel, upon which a pinion acts, this pinion is fixed on a vertical shaft (placed in the column to be seen on the seat, *see* Fig. 755), itself actuated by a vertical hand steering wheel. The somewhat considerable power needed to turn the fore-carriage thus is easily obtained, but less quickly than with the ordinary system. The driver's seat and interchangeable body are fixed on the steel underframe, which may carry a coupé, victoria, or delivery car body if wished. The motor mechanism rests on a small hinged frame, supported by a steel axle and spiral springs. In addition to the electric brake,. the car has a band brake and a shoe brake. Cars required to run only 50 km. or 60 km. (31 miles or 37·2 miles) without recharging have Planté type batteries, the cost of charging which the company estimates at 9½d. To run 70 km. or 80 km. (43·4 miles to 49·7 miles) batteries with inserted oxides are employed, the cost for maintaining which is from 2s. 4½d. to 3s. 2d. per run. The energy to charge the battery per km. is estimated by the constructors at 300 watt hours; that is, 2·8 ampère hours at 110 volts (484 watt hours per mile). Including lubrication, maintenance of accumulators, and carriage work, traction costs from ·95d. to 1·7d. per km. (1·5d. to 2·7d. per mile), according to the type of battery employed and cost of current. The car mentioned above is constructed on the Bersey system, as are also some cars made by the Compagnie Générale des Voitures of Paris. One car made by this firm, and exhibited in 1898, had a tubular frame, a steering lever, and divided axle and motor acting on the rear wheels by toothed gear; the accumulators were carried in two boxes, front and rear. Another car exhibited resembled this, but had a bar operating steering and controller, the former by moving around a vertical axis and the latter by displacements around a horizontal axis. Thus the driver had only a lever and a pedal to work.

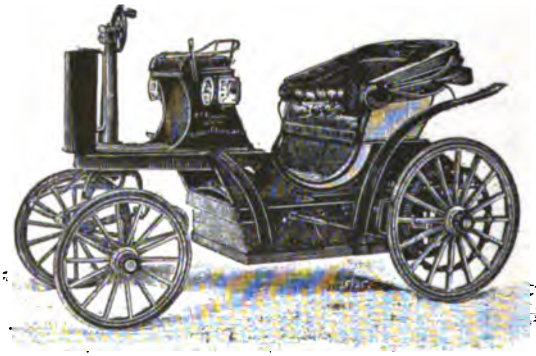


Fig. 755.—Compagnie Française des Voitures Electromobiles Electric Car.

The Bouquet, Garcin and Schivre car is shown by Fig. 756. The pastille accumulators have inserted oxides, and are claimed by the makers to have a capacity of from 22 to 25 ampère-hours per kg. (2·2 lb.) of plates at rates of discharge of 3 to 4 ampères. Thus these cars can run, without recharging, 130 km. (80 miles) on level roads and 25 km. (15·5 miles) on a rough road, the weight of the car being 1 ton; the accumulators represent one-third of this weight, and they are carried in two ebonite boxes under the seats; the coupling of the elements remains invariable. The motor has two brushes and two armatures wound on the same toothed core, Paccinotti system, in which the numbers of unequal windings are in the ratio of 5 to 3. The normal power is 4 to 5 h.p. for the very slight weight of 40 kg. (88 lb.), and it performs 1,500 revolutions for a speed of 20 km. (12·4 miles) per hour, and its electric efficiency is 0·93, the working efficiency being 0·87; thus the total efficiency, transmission included, is 0·80. The controller suitably inserts, according to the speed to be obtained, the unequal windings and the resistances. For starting, the two armatures are coupled in series with series excitation and starting resistances all shunted on the battery; thus the motor starts with the maximum electro-motive force and maximum resistance. In its successive positions the controller first gradually suppresses the resistance and then inserts the winding five only, then three only; finally for full speed windings five and three in opposition. Experience only can show whether this system is preferable to the employment of two equal secondary wires coupled in series or in shunt. The controller consists of two cylinders, the larger one being keyed on the axle of the apparatus and giving the forward speeds, and the smaller one being loose around the same axle and giving reverse motion at any speed.

The chief feature of the H. Monnard car is a motor with a single inductor and two armatures, forming one with the two parts of the axle, so as to make the differential unnecessary; the armature runs at a slight angular speed, namely, 600 revolutions or even less, to decrease losses by transmission. Figs. 757 to 759 represent the motor and axle. The field magnet has no yoke-piece, the windings c and d being made around the pole-pieces e and f. Owing to this arrangement the magnetic circuit is closed simultaneously by the two armatures, which are traversed by the same magnetic flux. Were there a yoke, each armature would receive only half the flux, and with the same number of ampère turns, difference of potential being the same, there would be an angular speed twice as great. V and

V^1 are collectors placed inside; the carbon brushes are pressed against them by springs r, r^1, r^{11}, r^{111}. The secondary wires, mounted on rollers, are loose on their shafts, and drive by two pairs of gear wheels the journals upon which the wheels are keyed. If the resisting power increases on the wheel rim, the corresponding secondary wire decreases its working and its counter-electro-motive force falls. The difference of potential augmenting at the terminals of the other secondary wire, the speed also increases; thus a differential gear is not required. The primary wire has a separate excitation, and four elements are specially devoted to it. Changes of speed are obtained by varied couplings of the four groups of accumulators and armatures and the two groups of accumulators and field magnets, so as to have six different speeds. The separate excitation enables working of the brake by recuperation at slow speeds; but if the accumulators coupled to the field magnets are exhausted before those coupled to the armatures, efficiency becomes low. The Vulcain accumulators, with Planté positives and negatives, weigh 396 kg. (871·2 lb.), one-half the weight of the car ready for the road. The consumption is 48 watt hours per kilometre-ton, and the maker asserts that the car can run 150 km. (93 miles) without new supplies. It has a brake of a rather peculiar type, which can be seen at F F^1, Fig. 757; it consists of a series of small shoes, S S^1, of lignum vitæ, threaded on a steel wire rope and separated from each other by copper tubes of about the

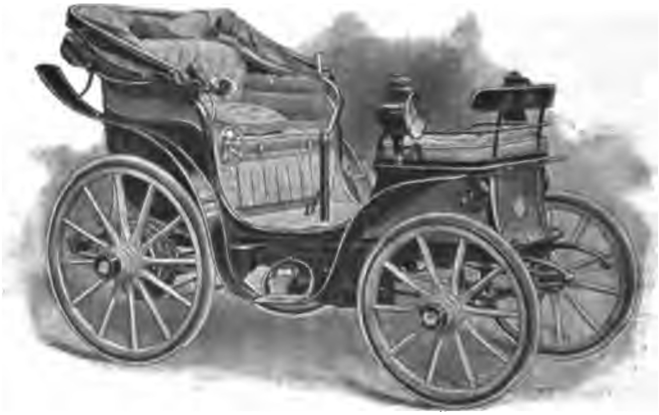


Fig. 756.—Bouquet, Garcin and Schivre Electric Car.

same length as the shoes. The two end shoes are united by a spring, which usually keeps the brake unlocked, but as soon as a pedal and

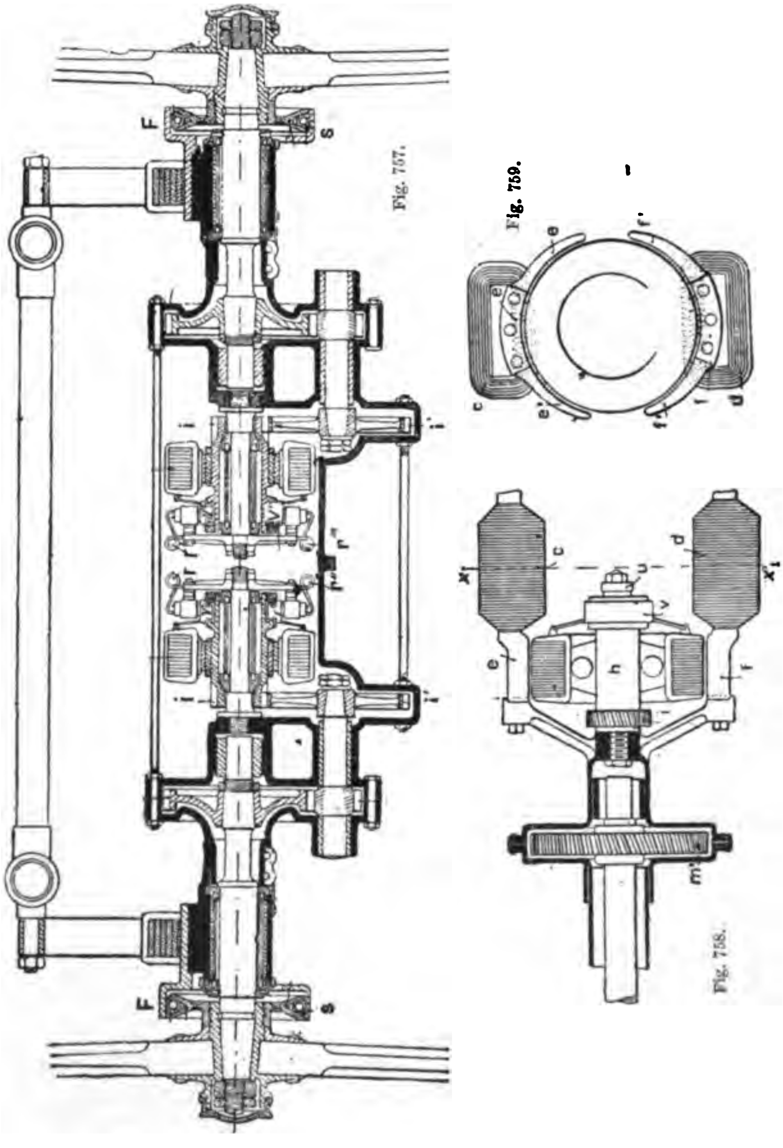


Fig. 757.—Monnard Electric Motor mounted on Axle. Figs. 758 and 759.—Sections of Monnard Electric Motor.

lever apply the first shoe to the groove fixed to the nave the other shoes are entrained and cause locking. It has been mentioned that the secondary wires are mounted on rollers; this is to avoid the wedging which occurs with ball bearings where the balls only touch each other at a point. The tempered steel rollers employed are 140 mm. (5·5 in.) long by 8 mm. (·315 in.) in diameter; around them are smaller rollers

Fig. 760.

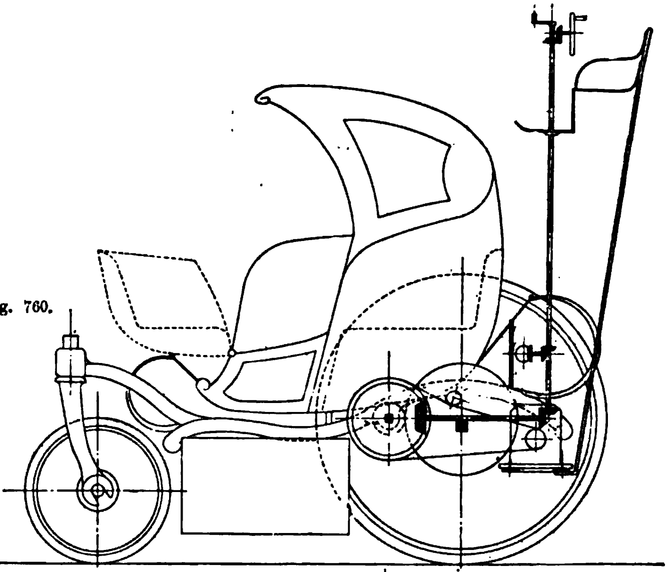
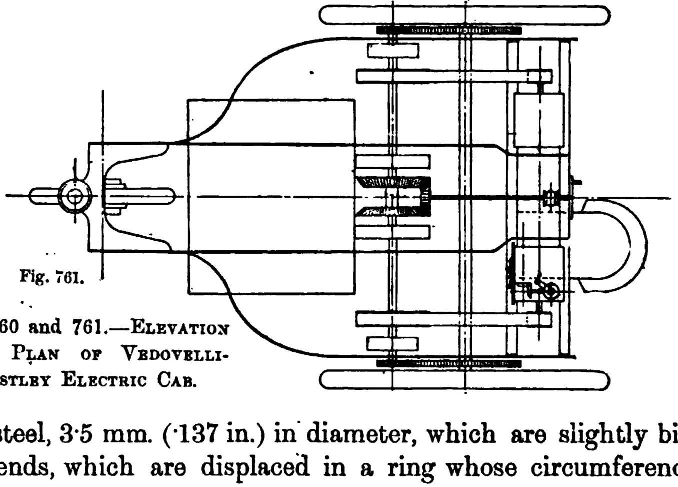


Fig. 761.



Figs. 760 and 761.—Elevation and Plan of Vedovelli-Priestley Electric Cab.

of hard steel, 3·5 mm. (·137 in.) in diameter, which are slightly bigger at their ends, which are displaced in a ring whose circumference is equal to their development; thus all gliding is prevented. The rollers are enclosed in oil-filled steel jackets made tight by leather Monnard estimates the coefficient of traction is thus reduced from 0·02 to 0·0093.

The Vedovelli-Priestley cab is an original car characterised by its apron (by aid of which it can be changed from a cab with two places to a vis-à-vis with four), its tricycle mounting, the driving of the steering driving wheels by two independent motors, a differential steering appliance which makes it pivot on the spot and by the optional addition of a small electrogenic apparatus which makes it possible to recharge the accumulators during a journey and stoppage (*see* Figs. 760 and 761). The fore-wheel, simply a bearing wheel for a small part of the total weight, resembles a furniture castor, it being movable around a vertical axle placed a little in front of its horizontal axis; it automatically takes the direction of the tangent to the trajectory of the car. As, moreover, the centre of gravity of the latter is under the axle, this tricycle mounting is not defective from the point of view of adherence in the steering wheel. Each motor, the position of which is shown by Fig. 761, has its motion transmitted to the side wheel by belts and toothed gear. The differential speeds are obtained by coupling the motor in series or parallel with other resistances. The controller, instead of being cylindrical as usual, is flat; Figs. 762 to 764 show its shape. The steering differential gear is on the shaft of the large belt pulleys

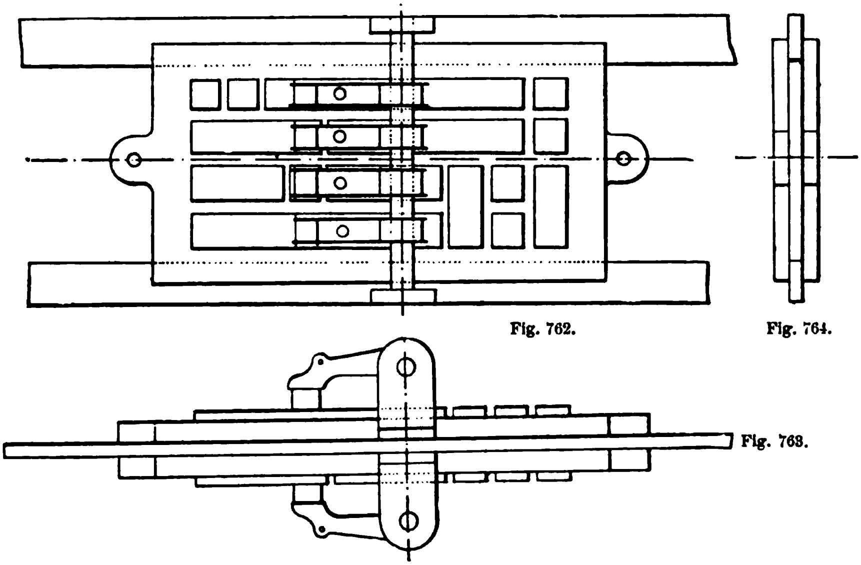


Fig. 762.

Fig. 764.

Fig. 763.

Figs. 762 to 764.—VEDOVELLI-PRIESTLEY CONTROLLER.

(*see* Fig. 765). Supposing in that figure, for sake of simplicity, that the two parts of the shaft directly carry the driving wheels. The pinion C, controlled by the hand steering wheel, gears with the toothed wheels B, having the same axis of rotation D as the pinions 2; these last gear with pinions 1 (carried by horizontal axles forming one with wheels B), which themselves are in gear with the inner teeth A, interdependent with the toothed wheels. When the hand steering wheel is motionless, and the wheels are driven by the motor, it is obvious that they must turn at the same speed. In fact, motion of the left wheel is transmitted by its pinion 2 to the corresponding pinion on the right, because the two pinions are keyed on the same axis, and pinion 2 by pinion 1 to the other wheel. Suppose that the hand-steering wheel turns first in the absence of any action of the motors on the wheels of the car. Wheels B turn in the opposite direction to each other, and entrain the pinions 1 in the opposite direction around axis D; the pinions 2, fixed together so as to form one, and drawn by equal and contrary forces, remain motionless. Then the pinions 1 roll on the pinions 2, but in the opposite direction to each other, and transmit inverse motions to the two driving

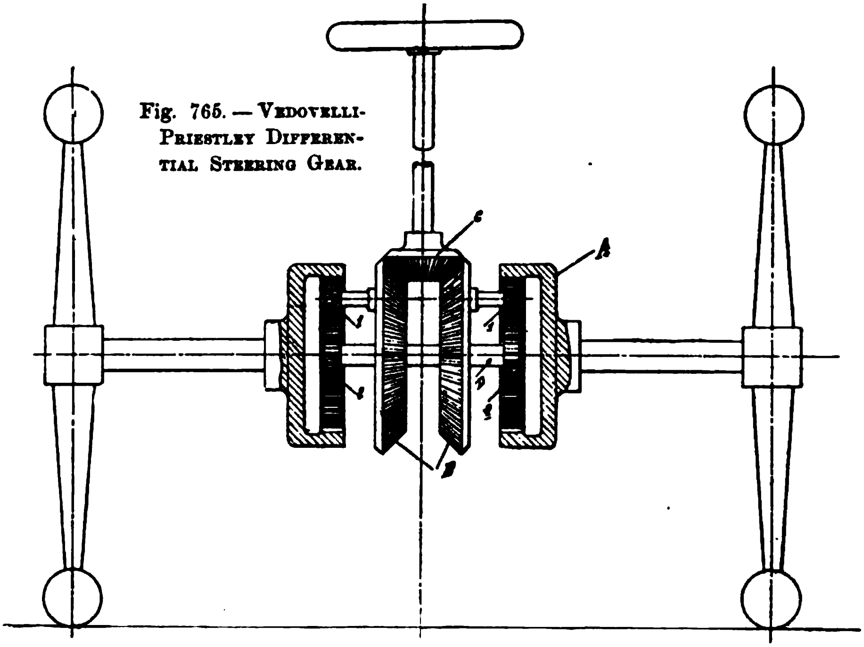


Fig. 765. — Vedovelli-Priestley Differential Steering Gear.

wheels, so that the car pivots on the spot. Finally, suppose that the hand steering wheel turns while the motors are driving the wheels. The motion imparted to the latter by the motors is composed with that produced by rotation of the fly-wheel; the pace of one is accelerated, whilst that of the other is retarded; then the car turns to the side of the latter. At the moment when the hand steering wheel stops, the car starts off in a straight line without the driver having to turn the wheel in the opposite direction to that which produced turning of the car. Two brakes, acting on the differential shaft, are controlled by the same lever as the controller, so that the brakes cannot lock when the motors are in circuit. This arrangement makes starting at full speed impossible after working the brake. A second foot brake switches off the current, which can only be switched back by bringing the controller to the position of stoppage. Retrograde motion is obtained by reversing the current, but this operation cannot be performed unless the controller is in the position of the stoppage. Thus every precaution is taken to prevent any working injuries to the accumulators, which run the car from 70 km. to 80 km. (43·5 miles to 49·7 miles) on one charge. A much longer distance can be travelled—even a trip of several days can be made—by carrying a portable electro generating apparatus for charging on the car, a petrol motor being coupled to a generating dynamo.

The Morris and Salom electric car can be defined as follows: The front axle is a driving axle, the two electric motors gear directly with the wheels; the accumulators usually are placed under the driver's seat; the rear wheels are steering wheels, and enable turning with small radius. The two axles carry a main frame which itself supports, at the back of the driver's seat, any kind of a body that is desired. The old electrobat No. 2, which won the 1895 Chicago race, was driven by two Lundell motors of 1,100 watts each, fed by 48 accumulator cells of the Electric Storage Battery Co., weighing about 285 kg. (627 lb.); the battery yields 4 kilowatt-hours. The maximum speed on a good level road (with wooden wheels and pneumatic tyres) was 32 km. (19·8 miles) per hour; the average journey was 45 km. (27·8 miles) without recharging. The Morris and Salom patents are now worked by the Electric Vehicle Co., which succeeded the Electric Carriage and Wagon Co., and now owns the New York electric cabs, hansoms and coupés. Each of its cars has 48 chloride elements, weighing, with their box, 650 kg.

(1,430 lb.). The four-pole motors perform 700 revolutions per minute, and develop a power of 2 h.p., sufficient, it appears, to give the car a speed of 19·3 km. (11·99 miles) on a good level road. The controller gives three speeds, either backwards or forwards, by variable coupling of the two groups of elements of the battery. This last can be charged without removing it from the car, but at the charging station recently built an exhausted battery is replaced by another.

The Sturgess Electric Motocycle Co. of Chicago ran a car in the *Times Herald* match, driven by a Lundell motor, fed by a battery of 36 elements, yielding regularly 30 ampères. The rear wheels were driving, and the front ones steering. The car, with its wooden wheels and indiarubber tyres, weighed 1,600 kg. (3,520 lb.) ready for the road.

A Riker car won the first prize in the track race of Providence, Rhode Island, September 7th, 1896. It had the form of a dog-cart with four seats, each of the rear wheels being driven by a 2,200 kilowatt motor fed with current by 32 chloride of lead elements; the normal capacity was 100 ampère-hours, and it weighed 365 kg. (803 lb.)—that is, about half the weight of the car. In a more recent type, Riker employs zinc lead accumulators, each element of which comprises six positive lead plates and seven negative copper plates electrolytically coated with zinc; 36 of these elements have an E.M.F. of 83·8 volts, and weigh 345 kg. (759 lb.) with their ebonite boxes, for a car of 825 kg. (1,815 lb.), which they could run for 68 km. to 80 km. (42·25 miles to 49·7 miles) at a speed of 19·3 km. (11·99 miles) per hour. For a discharge in ten hours their specific energy was estimated at 36·4 watt-hours; for the discharge in four hours it was only 29·15 watt-hours. This experiment with zinc accumulator cells did not give very encouraging results. In the case of light cars, Riker seems to have abandoned two motors, which, with equal power, cost more, weighed more, and had an efficiency less than a single motor. This single motor, which was exhibited by the Société Automobile at the Tuileries Exhibition in 1899, is hinged by two collars on the tubular jacket of the axle, and suspended to the body by a rod with two springs like a tramway motor. These springs form an elastic buffer against the reaction of the motor, to make starting smooth (*see* Fig. 766). The armature shaft drives, by aid of a pinion, a toothed wheel, mounted on the shaft, and also the pulley of a plate compressor, locking both rear and front, worked by a pedal. Brake and toothed gear are enclosed in a case placed on the centre of the rear axle. The latter is not divided, and its centre, which is reinforced, is protected by the tubular gear case surrounding it. The differential gear is placed on the nave of a wheel. The accumulators feeding this motor may be of any type. In France, Fulmen elements are employed, weighing 450 kg. (990 lb.), for a car of about 900 kg. (1,980 lb.). The two-pole motor has two drum-wound armatures; it is completely encased, but collector and brushes can easily be inspected by means of doors. Grouping of the accumulators and the primary coils give four speeds, 6 km., 12 km., 18 km., and 25 km. (3·7, 7·4, 9·9, and 15·5 miles) per hour. Backward motion is obtained in the first two speeds by reversing the current in the motor. When the mechanical brake is worked, a cut-off automatically breaks the current, and only allows it to be switched on again when the lever of the controller has been brought previously to zero; then the motor cannot be started at full speed. The frame, made of hammered steel tubes, has its small sides formed by the fore axle and tube surrounding the rear axle; one of the large sides is hinged around the fore axle, and the two can turn around that in the rear. Great pliancy results, the two always being applied to the ground, whilst the axles remain constantly in vertical parallel planes. The wheels have ball bearings with tangent spokes, and Hartford single tube pneumatic tyres. The front steering wheels pivot in place. For this purpose the axis of rotation, instead of being outside the wheel, is inside, and meets the ground at the point where the latter is in contact with it; the pivot is mounted on points inside a drum, around which the nave turns on ball bearings (*see* Fig. 767).

Columbia cars are built by the Electric Vehicle Company, of Hartford, Connecticut, which employs the cycle style of structure; the wheels have steel points, tangent spokes, and have a diameter of 90 cm. (35·4 in.) at the rear, and 80 cm. (31·4 in.) in the front, with pneumatic tyres of 75 mm. (2·95 in.); there are ball bearings for the car, motor, transmission gear, and steering gear; steering is accomplished by a non-reversible lever; the tubular frame is of nickel steel, and the tubes are large enough for them to be annealed. Those on the sides and in front of the car are doubly rigid, and are brazed at various points; the lower front tube supports a horizontal pivot around which the steering axle can move freely in a vertical plane. The rear of the frame is formed by a single tube, which acts as a bridge to carry the motor and axle. The accumulators are perhaps the parts on which least study has been expended. The positive plates are of the Planté formation, whilst the negatives have inserted oxides. Their capacity is 70 ampère-hours, with average rate of discharge of 25 ampères, and weight 160 kg. (352 lb.), assuming a run of about 50 km. (31 miles) on a good road. The efficiency is ordinary, but the constructors maintain that duration is a compensation. It is believed, however, that these accumulators have been abandoned. The Edie system four-pole motor is employed with forged iron carcase; the Gramme armature weighs 57 kg. (125·4 lb.), and gives 100 revolutions per minute, the current being at 75 volts;

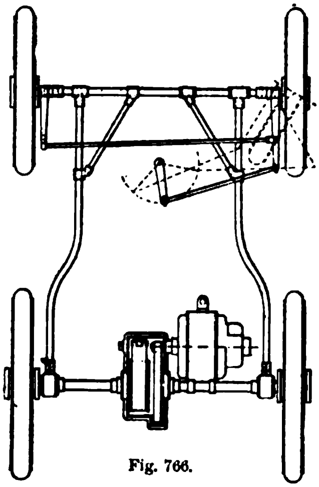


Fig. 766.

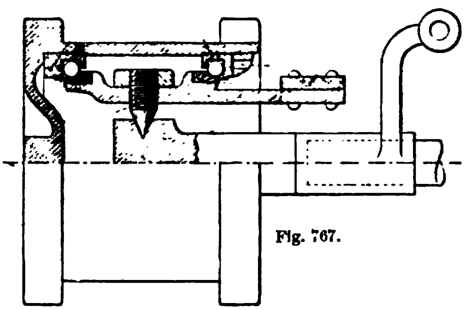


Fig. 767.

Fig. 766.—Riker Electric Car Chassis.
Fig. 767.—Wheel Nave of Riker Car.

the power is a little less than 2 h.p., but this can be doubled for half an hour without danger. Its efficiency is estimated at 80 per cent., that of the transmission 90 per cent., and the final efficiency 72 per cent. The speeds, 5 km. to 10 km. (3·1 miles to 6·2 miles) are obtained by varied coupling of the accumulators and the field magnets of the motors. All the movable connections have holes of certain diameter for the positive and another for the negatives, to avoid all possible error. An electric lamp fixed at the end of a long flexible cord enables the parts of the car to be inspected conveniently at night. These and other details give a happy finish to a very careful general structure, which represents everything that is best in American automobile practice. There are three types of Columbia cars, which differ in the motor and transmission wheels. The phaeton with two places (Figs. 768 and 769) had a single motor of less than 2 h.p., mounted on a hollow shaft concentric with the rear axle, which it controls by two pairs of reducing gear wheels, the last wheel of which is simply the differential toothed wheel. All this forms a very compact ensemble, which does not deprive the car of its elegant carriage aspect. The motor power may be regarded as low for a car which, with two passengers, does not weigh less than 1 ton. The motor is fed by four batteries, and three speeds are given by coupling these batteries in various ways, the field magnets remaining in series at a speed of 19·6 km. (12·1 miles) per hour Consumption is 73 watt-hours per kilometre-ton (122 watt-hours per mile ton). The body is suspended by three half-nipper springs placed transversely. The car has four places facing the front, and two motors, each controlling by a pinion a toothed crown enclosed in a case and mounted on the driving wheel. When the two motors are connected in series they give the same power, and as long as the two wheels turn at the same speed they run at the same voltage. In a curve the inner wheel decreases its speed, and the corresponding voltage of the motor diminishes, the difference being transferred to the other motor, the required increase of speed resulting for the outer wheel. This arrangement does not seem to have given all that

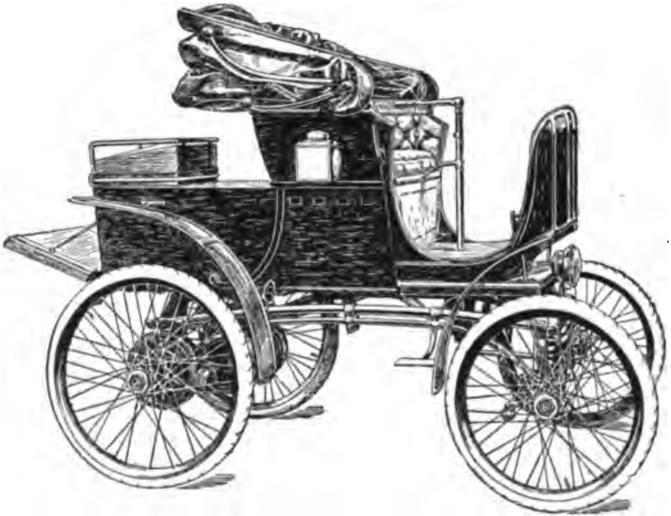


Fig. 768.—Columbia Electric Car.

was expected. Consequently the car with four places back to back has one motor placed like that of the phaeton with two places. This car, weighing 1,300 kg. (2,860 lb.) with its four passengers, consumes 35 ampères on level ground. The accumulators are divided into six groups of seven elements; there are four forward speeds and three back. The Columbia cars have a rather peculiar crown brake, as shown by Fig. 770, in which the wheel is shown removed to the right. A bronze crown fixed to the underframe surrounds the toothed wheel drum of the differential, only giving passage to the pinion gearing with this drum. The differential gear has a pulley upon which a band of cleft steel is applied by a set of pedal-operated levers. The pedal begins by switching off the circuit, and can be fastened at a suitable notch when the locking has to be maintained. The controlling of the car is operated by four parts: the steering lever worked with the right hand, the controller with the left, the mechanical brake with the right foot, and a heel piece for reverse motion worked with the left foot. The controller is very simple, but does not allow of electric locking of the wheels, nor of recuperation, and if the car is stopped by the

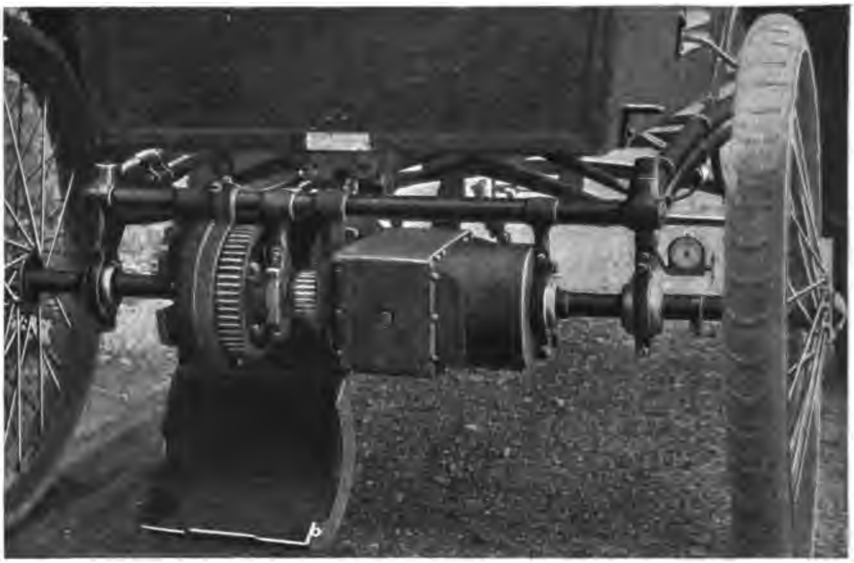


Fig. 769.—Rear View of Columbia Electric Car.

mechanical brake without bringing the controller to the stopping point, there is a risk of starting off again at third speed. The Société Electromotion exhibited in 1899 a pretty type of Columbia car with one and two motors, all having Phœnix accumulators.

Cleveland cars are built by the Cleveland Machine Screw Company according to plans by Sperry. The accumulators weigh 375 kg. (825 lb.) for a motor of 900 kg. (1,980 lb.), and feed a bipolar series motor giving only 2 h.p. under 86 volts and 1,800 revolutions per minute, but capable of supporting an extra charge of 150 per cent. It is attached to the centre of the rear axle by two ball bearings on either side of the differential, and united to the frame by an elastic suspender. It is surrounded by an aluminium gear case, and transmits motion to the differential by a system of toothed wheels with double reduction. There are three different speeds, 4 km., 8 km., and 16 km. (2·48, 4·97, and 9·9 miles) per hour, obtained by varied couplings of the accumulators. An accelerator acts by decreasing excitation by shunting the field magnets. By regulating the shunt a variable speed is obtained, which may attain 32 km. (19·9 miles) per hour. There is also a mechanical speed-changing gear. The car has three brakes, electric, mechanical, and shoe. Steering is operated by a loose bar; the sockets of the steering wheel pivots are inclined so that their prolongations intersect the ground at the point of contact of the wheels. The main frame is formed of two tubular triangles connecting the axles; and it is reinforced by rods joining two points of the axle to two points of the side bars. The body rests in front on the middle of a spring, by a horizontal axis which allows the axles to rock in a vertical plane; at the rear it rests on two longitudinal nippers. The controlling parts are very simple; the steering bar also works the controller and acts as a stopping lever and brake lever. The brake is worked by a pedal and the accelerator by a button.

With regard to charging accumulators, charging the batteries on the car itself involves the spilling of corrosive liquid, and the evolution of more or less explosive gas. The Aubervilliers works now have a well devised plant by means of which spent batteries are replaced rapidly by fresh ones. The method of doing this is to run the car over two inclined planes, one for the front wheels and the other for the rear, some centimetres above the platform of a hydraulic lift. A truck is raised by this platform and applied against the battery; the spiral springs suspending the latter are compressed and the chains unhooked. Then the lift descends, and the truck conveys the battery to the place for recharging, running along railway lines and travelling platforms. An inverse operation brings the new battery to the car.

As stated in Chapter VIII., properly designed electric cars can return energy to the batteries when running downhill, the momentum of the vehicle causing the motor to act then as a generator and to form a convenient automatic brake. The following statement of a case in point is due to Mr. H. F. Joel: At the U. S. A. Chislehurst trials in November, 1900, the highest current recorded for Riker car No. 3 when ascending the steepest hill (gradient 1 in 10) was 119 ampères, and in descending the same hill a back charge of 35 ampères was given to the battery. The total weight of the car, with passengers, was 965 kg. (19 cwt.). The tractive resistance may be taken for rough gravel and macadam roads as 22·6 kg. (50 lb.) per ton on the level, that is 21·5 kg. (47·5 lb.) for this car; then the effective horsepower required to propel the car up an incline of 1 in 10, at a speed of 9·65 km. (6 miles) per hour, would be 4·2-h.p. This corresponds with the actual current observed, namely, 119 ampères at 30 volts to 32 volts, taking the efficiency of the electric motors with connecting wires and contacts at 84 per cent. The additional power required to ascend the gradient of 1 in 10, and included in the 4·2 effective h.p. given, is $\frac{W \times V}{m \times 33{,}000}$ h.p.; where V is the speed of the car in feet per minute, W is the total weight of the car in pounds, and the gradient is 1 in m. In this case the required power will be

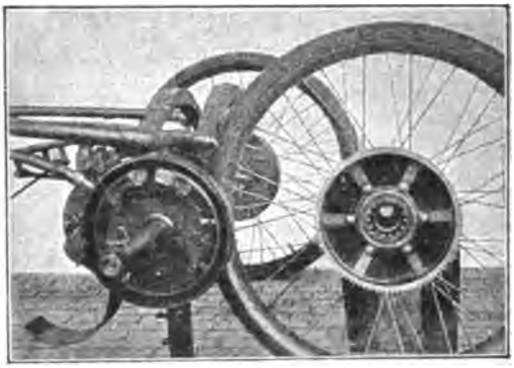


Fig. 770.—Columbia Crown Brake.

$\frac{W \times V}{10 \times 33{,}000}$ h.p.; and it is evident that, when descending a hill of 1 in 10, a considerable part of this power, less the tractive resistance, is available for recuperating or charging the battery. Allowing 25 per cent. higher speed when going downhill for generating, and taking the efficiency again at 84 per cent., the actual power available is 1·9 h.p.; which, at 40 volts, will give 33 to 35 ampères as the return charge to the battery, corresponding with what was observed. The duration of the charging is less, because the speed is increased 25 per cent.; but taking this into account in the example referred to, at the speeds given there would result a return of about 23·5 per cent. of the energy taken when ascending the same hill; and this agrees with numerous observations made on many runs. Of course the speed downhill would be comparatively low—only 12 km. (7·5 miles) per hour; but on a hill, say, 4·83 km. (3 miles) in length, the current returned would be between 10 ampère hours and 20 ampère hours, which would be sufficient to propel the car 4·83 km. to 8 km. (3 to 5 miles) on good level roads—a gain which might be very convenient at the end of a long day's journey. If the car were sent downhill at 24 km. (15 miles) per hour, it would still give a back charge to the battery, but for only half the time. One direct advantage due to this recuperation is depolarisation of the batteries, which restores them to their maximum electromotive force after their heavy discharge when ascending a hill. In many long runs on electric automobiles, Mr. Joel has not used the mechanical brake at all, stopping and reducing speed solely by the reactive effect of the motor. This renders the control of an electric car simpler than that of any other self-propelled vehicle; and with shunt-wound motors there is no loss of energy in stopping, but rather a gain.

The following information as to the ratio of the weight of the vehicle to the weight of the power-giving battery is also due to Mr. Joel. Generally, as the ratio of the weight of the battery to the weight of the vehicle increases, so the distance that such a vehicle can be run on one charge is increased: but of greater importance from a practical point of view is the load-carrying capacity, and the ratio of the weight of the useful load to the weight of the battery and vehicle. Taking the efficiency of the motor and gear at 75 per cent., a battery of accumulators weighing 305 kg. (6 cwt.)

will give an effective power of 10-h.p. hours, or 30·48 kg. (67·2 lb.) for 1-h.p. hour. Assuming an output of 33 watt hours for 1 kg. (15 watt hours for 1 lb.) of complete battery, a 305 kg. battery would convey itself against a tractive resistance of 22·6 kg. (50 lb.) per ton (about $\frac{1}{44}$) at the rate of 19·3 km. (12 miles) per hour for a total distance of 402 km. (250 miles) equal to 120 ton-km. (75 ton-miles). Assuming that the vehicle to convey this battery would weigh 305 kg. (6 cwt.), the distance that could be run with vehicle and battery would be 201 km. (125 miles), and with a load of 152 kg. (3 cwt.)—driver and passenger—the distance would, under the same conditions, be reduced to 161 km. (100 miles), with the same ton-mileage throughout. With twice the load, that is, 305 kg. (6 cwt.), the distance of the run would be reduced to 135 km. (83·8 miles); and with three times the load, that is, 457 kg. (9 cwt.), the distance would be further reduced to 115 km. (71·4 miles), again equal to 120 ton-km. (75 ton-miles). The cost of carrying the useful load would be 0·55d. per ton-km. (0·9d. per ton-mile) for the 152 kg. (3 cwt.) load; 0·34d. per ton-km. (0·55d. per ton-mile) for twice that load; and 0·28d. per ton-km. (0.45d. per ton-mile) for thrice. Thus as the load is increased, the cost of conveying the useful load per ton-mile is reduced; but there is a limit which is soon reached when the car must be made stronger and heavier to carry the increased load, with a consequent increase in the running cost, in the first cost, and also in the allowance for depreciation and interest.

CHAPTER XX.

PETROL-ELECTRIC AUTOMOBILE CARRIAGES.

ELECTRICITY has rendered valuable assistance in the development of the petrol motor by supplying a means of igniting the explosive mixture in the working cylinder; but there is, however, another application of electricity which promises to be of increasing importance as a means of replacing the mechanical speed-changing gears now in common use on petrol cars.

The greatest inconvenience of the petrol motor, as has been shown in former chapters, is its want of elasticity; and to enable it, in spite of this defect, to give the required maximum of work at starting and when ascending gradients, it must have an excess of power which there is no use for in ordinary circumstances, where the petrol spirit yields only a part of its theoretical heat energy. To obtain variable speeds with a petrol motor there has to be a complicated system of spur gears or of pulleys and belts, which, of course, wastes much power. On the other hand, a large amount of energy can be carried on a petrol car, and further supplies can be obtained easily on the road. Opposite in every way to this is the electric motor; this has remarkable elasticity, being able to bring the requisite amount of energy into play at each moment and so dispense with mechanical speed-changing gear, but its great disadvantage is that frequent new supplies are essential. This balancing of advantages and disadvantages naturally has led to the idea of associating two motors, one of each type, in the same car.

In this system an electric generator or dynamo is coupled direct to the petrol motor, and the current furnished is employed to operate electric motors which drive the car in one or other of the ways usually adopted in the electric vehicle pure and simple. The combined engine and dynamo thus represent, roughly speaking, the battery of accumulators employed on the electric car, and have the advantage of being independent of a source of electric current and of being considerably lighter, but of course it is not so free from noise and vibration as is the absolutely silent motive power of a secondary battery. The current is led to the motors through a controller, which enables various speeds to be obtained by altering the electrical grouping of the motors and their parts. The advantages of this system are the ease and pleasantness of the control as in a purely electric car, the controller effecting a change of speed gradually, without jerk or jar.

There are two types of petrol-electric cars; in one a dynamo driven by the engine furnishes current to electric motors; in the other there is, in addition, a small battery of accumulators acting as a kind of flywheel to store up energy when it is not required for propelling the car, and to furnish it in increased quantity when extra power, as for hill climbing, is needed. The former type is exemplified by the Mercedes-Lohner-Porsche car, which was built for the abortive Nice-Abbazzia Race. The latter is well exemplified by the Fischer omnibus, described on pp. 740 to 744, and in the Fischer lurries, described on pp. 744 to 746, and in the Belgian Pieper car, which for some reason does not appear to have been so successful.

Of the two types of petrol-electric car, that exemplified by the Fischer vehicles appears to be the better. The engine driving the dynamo is enabled to run constantly at its highest and most efficient speed irrespective of the rate at which the car is travelling. A comparatively small battery—capable of running the car for, say, half an hour by itself—is connected in parallel with the motors, so that the electric current from the dynamo may be said to have two paths open to it. When the car is travelling at a moderate pace along the flat, the motors do not take all the current, but some of it goes to charge the battery. If more energy is required to drive the car, the motors may take all the current furnished by the dynamo, in which case the battery will not receive any. If additional power is needed, as when travelling uphill, the motors take the extra energy required from the cells, and considerable hill-climbing power results. As the motors bear the same relation to the battery as the motors of an ordinary electric vehicle do, the car has a similar degree of flexibility and softness in changing from one speed to another. It will be observed that the battery performs the functions of a flywheel whose action is not dependent on time or speed. Above all, the combination presents the advantages of recuperation and electric breaking, so valuable in the electric car. When running down a long gradient, instead of wasting energy in wearing out brakes, the motors may be made to act as generators, and to put current back into the cells, thereby assisting the action of the dynamo. Such control is gentler and more agreeable than that of ordinary braking, and reduces the fuel consumption of the petrol motor.

The weight of a petrol-electric car is a consideration. The whole mechanism is essentially heavier than that of a vehicle in which a petrol engine drives directly through change-speed gearing, although the weight of the electric motors may be deducted from that of the change-speed mechanism dispensed with in the petrol-electric system. The dynamo is constructed to form the flywheel of the petrol engine, and from its additional weight the ordinary flywheel allowance for an engine of considerable construction may also be deducted. There still remains, however, a considerable extra weight, without taking into consideration that of the battery, which need not be very heavy, as its capacity need only be small. An advantage not yet referred to is that of starting the petrol engine by supplying current to the dynamo, which then runs as a motor, so that a petrol-electric vehicle can be started almost as easily as an electric car.

Accumulators for petrol-electric vehicles must have high discharge rates for short periods, and so the usual light traction battery is hardly suitable, as though its weight may be low for long discharge rates, for short but high discharges the weight must be great. The best existing type of battery is one of the Tudor class, having a light, large-surface Planté positive plate and a light pasted negative. Such a battery has been employed successfully on tramcars in Dresden.

The Fischer type of vehicle is proving itself highly successful for lurries and omnibuses, where actual weight is comparatively unimportant. How far it can be adapted for passenger vehicles and pleasure cars of the lighter kind remains to be seen.

The Lohner-Porsche system is essentially lighter, there being no battery, but the only advantages gained are the suppression of change-speed mechanism, and the more pleasant effect which electrical variation of speed permits. The battery-flywheel effect is not obtained, nor the recuperating and electrical braking effects.

And in addition the engine has to be started in the same way as an ordinary petrol car. However, in the latest type of car there is, as described on p. 736, a battery of six cells which start the petrol motor and light the car lamps.

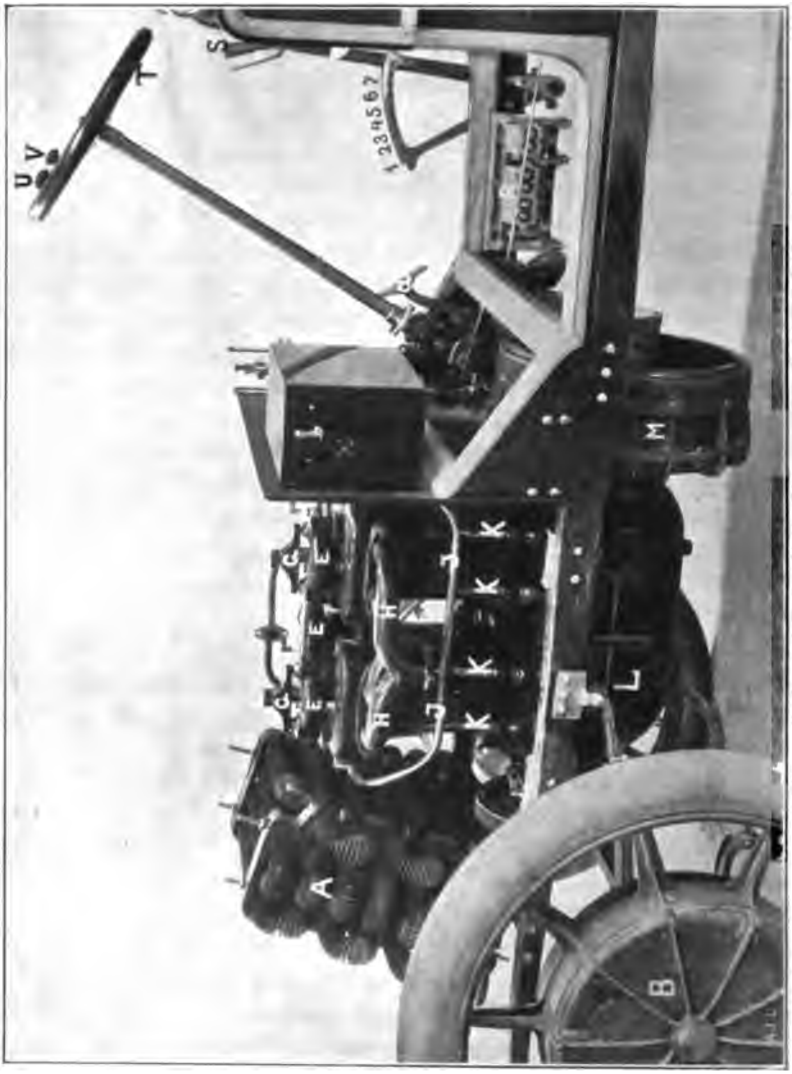


Fig. 771.—Front Part of Lohner-Porsche Petrol-Electric Car.

The first working petrol-electric car, it is believed, was W. H.

Patton's arrangement that was exhibited at Chicago. Patton had had experience in tramcar construction, and his tramcars, dating from 1890, each had a gas engine driving a generating dynamo, which supplied current to two electric motors which drove the car wheels. Heilmann had a similar arrangement on two electric locomotives built for the Western Railway of France, though he used a steam engine, not a gas engine. In Patton's tramcars, inserted between the dynamo and the driven motor, was a battery of accumulators, which formed a reserve of energy, to be drawn on when required. In Patton's first real petrol-electric car, a petrol motor ran a dynamo, which gave its current to a battery of accumulators; these ran an electric motor, which finally drove the vehicle.

Such a system as is outlined above necessarily is complicated, but in May, 1896, H. J. Dowsing patented a much simpler combination. A continuous current dynamo is fixed on the car and is driven by the surplus power of the petrol engine, the dynamo yielding current with which to charge accumulators. The connections are so arranged that when the speed falls below normal, the dynamo becomes a motor driven by the accumulators it previously was charging, belts transmitting the motion to the axle; in the same way the dynamo-motor serves for starting the petrol engine. The motor and the accumulators do not have to sustain heavy loads and can be of light construction.

The Pieper car, exhibited at the Tuileries in 1899 by the Liège firm, is on the above system.

The latest type of Lohner-Porsche car has front driving wheels, and the front portion of it is illustrated in Fig. 771. The 15-h.p. Panhard Centaure four-cylinder engine has a Krebs carburetter, and is fixed to the main frame. Two independent commutators are provided, and the high-tension ignition plugs for the cylinders are in duplicate. The petrol engine is coupled direct to the armature of the dynamo M, this armature replacing the usual flywheel and running inside a circular field-magnet casting, which is more or less secured to the main frame. The field magnets are not exactly fixed to the frame, because they are capable of a slight rotary motion through a few degrees. They are normally held in this respect up against a stop by means of a spring, and they can only overcome the pull of the spring when the load upon the dynamo exceeds a certain amount. The actual position of the field magnets therefore varies in accordance with the load, and they are connected in such a manner with the petrol engine that they govern it as would an ordinary centrifugal force governor.

The power is transmitted electrically to the front wheels, in whose hubs the motors B are enclosed. The speed of the vehicle is varied by means of the lever S, which is connected with the controller R in such a manner as to complete the required electrical connections between the dynamo and the motors as it moved to the different positions about its quadrant. A small battery of accumulators, consisting of six cells only, is provided on the car. They are used primarily for the ignition, and are also employed for starting the petrol motor by means of the dynamo, and for the lamps. The cells can be recharged from the dynamo when necessary. The electrical connections made by the controller enable the motors in the wheels to be used as powerful brakes, and mechanical brakes are applied to the hubs of the rear wheels by pedal, *a*, simultaneously with them. The vehicle is said to be capable of attaining a speed of nearly 80·5 km. (50 miles) an hour on the level; its weight is about 813 kg. (16 cwt.). In Fig. 771, A is the radiator, E induction pipe, G valve yokes, J water connection, K exhaust valve-stems, H exhaust pipe, L crank-case, and T hand-steering wheel with ignition and mixture regulators, U V.

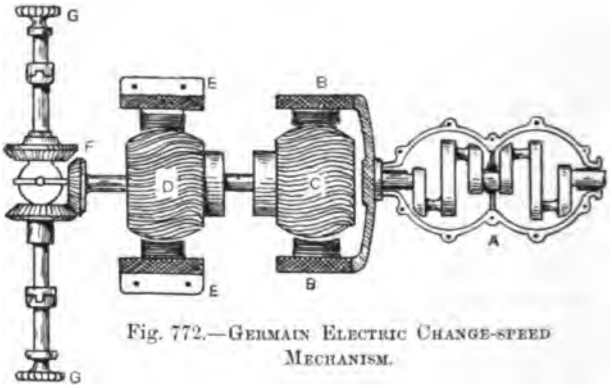


Fig. 772.—Germain Electric Change-speed Mechanism.

The Germain petrol-electric car may be more correctly termed a petrol car with an electrical change-speed gear, and it is a different type of car from those in which the whole power of a petrol motor is employed to drive a dynamo, and in this way is transmitted to the electric motors; because in the Germain car only part of the petrol motor's power is so employed, and there are no accumulators to form a reserve of energy. Its advantages are the same as in the other types of petrol-electric car so far as concerns the flexibility between motor and road wheels and facility in varying the speed and torque of the driving wheels without altering those of the petrol motor. Its disadvantage is the absence of accumulators which in the other type of car store the surplus power and give increase of speed for short periods; but a compensation is the lower weight of the car and a more efficient transmission.

The Germain apparatus is more obviously an electrical change-speed gear when the main clutch on an ordinary petrol car is considered a part of the speed gear. It is shown diagrammatically in Fig. 772, and some of the electrical connections are represented in Fig. 773. The petrol motor A is fixed in front of the car, with its crank-shaft lying longitudinally. The power is ultimately transmitted by side chains to the rear wheels from a transverse countershaft, G, on which is a differential gear, this being petrol car practice. Two series-wound dynamos are placed between the petrol motor and the countershaft, their armatures, which are in line with one another and with the crank-shaft, being fixed upon a longitudinal shaft, at whose rear end is a bevel wheel, F, which engages with a corresponding wheel on the shell of the differential gear. The foremost dynamo C acts when required as a magnetic clutch, and its field magnet B is fixed to the forward end of the crank-shaft, so that it revolves about its armature C at the same speed as the petrol motor. The rearmost dynamo D acts for the most part as an electric motor, although it is also used as a dynamo in order to give a "braking" effect when required. The field magnet E is securely fixed to the main frame of the car, and its armature D revolves at all times at a proportional speed to the road wheels.

For the sake of clearness, rearmost dynamo D is here called the motor, foremost dynamo C the dynamo, and the petrol motor A the engine. It will be noticed that the field magnet B of the dynamo forms a flywheel for the engine; each armature has a separate commutator, from and to which the current can be taken through brushes in the ordinary way. Variations of speed of the car are effected entirely by a controller, which makes the necessary electric connections between the dynamo, motor, and a variable resistance coil. The resistance R can be introduced across the terminals of the field magnet windings of the motor, and Fig. 773 shows diagrammatically most of the switch connections for the various speeds, although those for producing a braking effect are not included. Assuming that the engine has been started, and the car is at rest, the dynamo field magnets will be revolving about the armature C. The electric circuit throughout is open, no current is generated, and there is no tendency for the armature to revolve. For starting the car the dynamo is connected in series direct to the motor (switch not shown), and the current flows in the direction shown by the arrows through the motor, causing it to start in the same direction in which the engine is running. Under these conditions the car travels at a speed depending upon the gradient of the road and its tractive resistance.

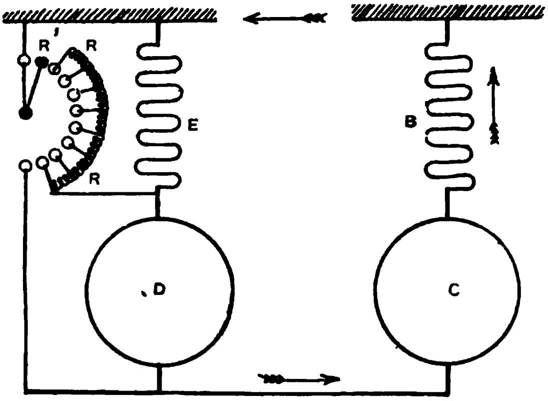


Fig. 773.—Germain Electrical Connections.

Part of the power imparted to the driving wheels will be derived direct by the magnetic pull of the dynamo field magnets on its armature, and the other part will be derived by the pull of the motor. The faster the car runs the more nearly will the speed of the dynamo armature correspond with that of its field magnets, and consequently the amount of current supplied by it to the motor will be less, and the motor will be doing less work. The reduction of current, however, also affects the pull of the dynamo field magnets on its armature, because the magnetism in both is thereby reduced. On the other hand, the slower the car runs the greater will be the relative speeds of the armature and the fields of the dynamo, and consequently the clutch effect between these parts will be increased, and the power of the motor will also be greater. For increasing the speed of the vehicle the switch R[1] is moved to its first position, thus introducing a resistance across the field magnets of the motor, and so increasing the normal speed of the motor, in addition to increasing the quantity of current flowing through the main circuit, and hence the magnetic direct pull of the dynamo. Gradual increases of speed are made by reducing the value of the resistance R, and thus gradually and ultimately completely short-circuiting the motor field magnets with greater and greater effect. In practice, twelve of these resistance contacts are provided, equivalent to twelve different car speeds. For the top speed the switch R[1] is moved to its lowest position in the diagram when the entire motor is short-circuited, and consequently it takes but little relative speed between the armature and the field magnet of the dynamo to generate the necessary current for magnetising these two parts sufficiently to obtain a direct drive to the armature shaft. It should here be pointed out that this magnetic clutch provides a very flexible coupling between the engine and the road wheels, the effect of varying gradients on the road being merely to change the relative speeds of the field and the armature of the dynamo. There is a risk of the dynamo winding being burnt up if this top gear is switched in suddenly, or when climbing a steep hill, unless the output of the dynamo is sufficient to withstand the heavy overload.

Reversing is effected mechanically, and cannot be obtained by the electrical apparatus. The well-known method of bringing alternative bevel wheels on the differential into mesh on one side or the other of the bevel wheel F on the armature shaft, has been resorted to, this gear, of course, only being changed when the car is at a standstill. A powerful electric brake, however, is available, and is operated in practice by the same controlling lever which gives the variations of speed. Four different degrees of retardation can be obtained, the handle being moved back over four contact pieces; the motor connections are so grouped, with variable resistances introduced, that the motor acts as a dynamo.

The Hart petrol-electric car may be classed with the Germain, inasmuch as the electrical arrangements are in the nature of a system of transmission only. The main frame, of channel steel filled with wood, is supported upon semi-elliptic side springs above the rear axle, and upon transverse springs above the front axle; the rear springs are longer in front of the axle than behind it. The side members of the frame are stiffened by tie-rods passing along beneath them, and giving them a girder construction. The usual distance rods connect the back axle with the frame, and similar rods are employed for keeping the front axle parallel with the other. These rods are pivoted to the ends of the axle, close up to the forks which provide the steering heads, and at their other ends they are pivoted to the side member of the frame, a little forward of the dashboard. The 40-h.p. four-cylinder petrol motor is fixed to the main frame, and has its inlet valves arranged above the exhaust valves; the former are operated mechanically from an enclosed chain-drum cam-shaft which passes across above them, the front end of the cam-shaft having a pulley secured to it, by which it drives a fan placed immediately behind the honeycomb radiator forming the front of the bonnet. A centrifugal force governor acts upon a throttle valve, and ignition is high tension timed by a small lever on the steering pillar. Another similar lever alongside it is connected to the carburetter. A twenty-kilowatt enclosed four-pole dynamo is fixed to an angle steel underframe, immediately behind the petrol motor, and its shaft is connected with the crank-shaft by a flexible coupling. Its current is led through a controller to an electric motor fixed to the main frame immediately behind the differential countershaft, from which the side chains pass to the rear wheels. The shaft of the electric motor lies parallel with the countershaft, and a spur wheel on its left end meshes with a corresponding spur wheel secured to the shell of the differential. The controller connects the dynamo with the electric motor and with resistance coils so that the speed can be regulated at will. The controller is operated by a horizontal lever fixed to the steering pillar beneath the wheel. The usual brakes are fitted to the hubs of the rear wheels, and a brake drum is also fixed on the right end of the electric motor shaft. The car is capable of attaining high speeds, it being obviously of great power.

The Fischer omnibuses are the most familiar type of heavy petrol-electric vehicle. One of these is a private 'bus, with accommodation for seventeen passengers—twelve inside, one beside the driver, and four on a seat behind the driver, and its appearance is seen in Fig. 774. The general arrangement of the undercarriage and machinery is shown in Fig. 775. The petrol engine is mounted across the angle steel frame beneath the driver's seat, and is directly coupled to a multipolar dynamo fixed immediately in front of it. The crank-shaft lies at right angles to the front axle, and a flywheel is fitted to its rear end. The engine is of the three-cylinder vertical type, and is described on p. 260. The float-feed atomising carburetter is fixed above the dynamo, and the three exhaust pipes pass from the engine to an exhaust box placed transversely across and beneath the frame. The circulating pump is driven as described on p. 260. There is a horizontal radiator placed centrally underneath the vehicle, and a large supply tank behind the rear axle. The current generated by the dynamo is led through a controller on the left side of the driver, and in the centre of the car, to two bi-polar motors driving the rear wheels. These motors are drum or shunt wound and entirely enclosed, and although their shafts are independent of each other, they are connected rigidly together.

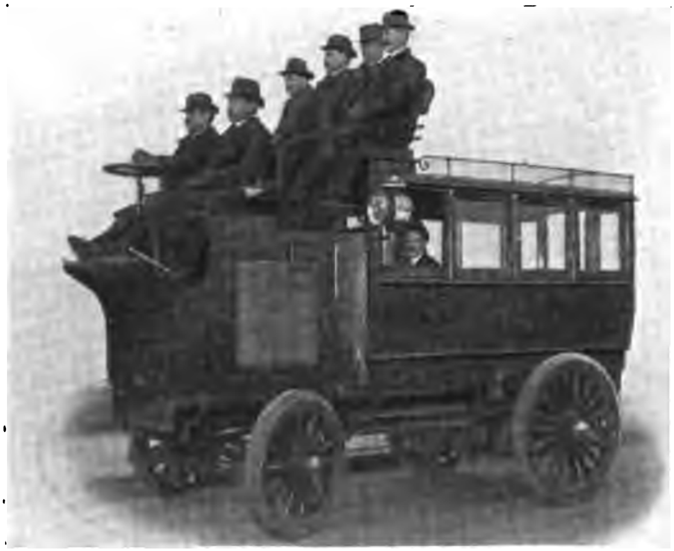


Fig. 774.—Fischer Petrol-Electric Omnibus.

They are supported rearwardly on the back axle, about which they are free to swing, and their weight is taken forward by spring suspension from the frame. Spur wheels are fitted to the outer ends of the shafts, these meshing with corresponding wheels on intermediate shafts, rigid with which other pinions gear with spur wheels fixed to the rear wheels. A double reduction of speed between the motor and the wheels is thus provided. Each gear is contained in a dust-proof case. The motors normally give 5-h.p. each at 600 revolutions. Each of the inner ends of their shafts carries a brake drum, a pedal to the right of the steering pillar being connected in such a manner as to apply the brake simultaneously on both. The petrol motor runs at a normal speed of 600 revolutions a minute, and develops about 10-h.p. on the brake. The dynamo has a normal output of five kilowatts, and its voltage at normal speed is 110.

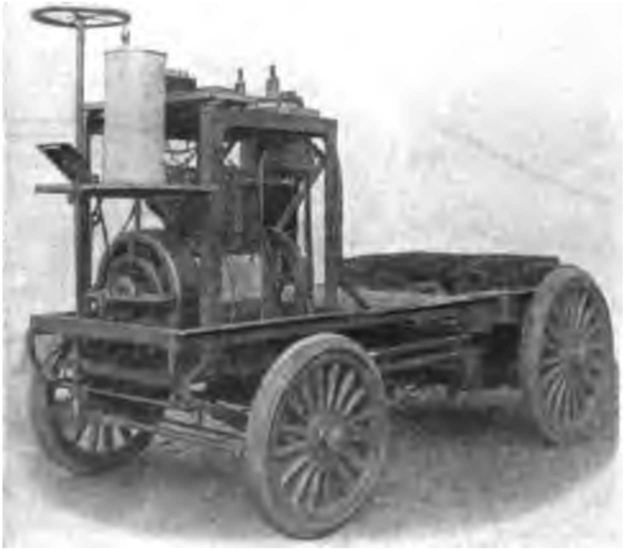


Fig. 775.—Fischer Omnibus Chassis.

The series parallel type controller is arranged with five forward positions and three in a reverse direction. The connections made by it for forward running include—the motors in series with a starting resistance introduced; a similar connection with resistance cut out:

the armatures in series and the field in parallel; and the two motors in parallel. The forward speeds vary up to ten miles an hour, and those provided for the reverse up to five miles an hour, although, obviously, by changing the ratio of the reducing gear between the motor and the wheels any desired speeds can be provided for. The hand lever operating the controller is rigidly connected with a vertical contact-making drum, and the handle, which projects vertically from the end of the lever, is fitted with a sliding rod connected with a catch, so that the lever cannot be moved to either of the "reverse" positions unless the rod is depressed.

A battery of fifty accumulator cells is arranged beneath the seats inside the 'bus. These cells are of the Madden Chloride pattern and have a capacity of ninety ampère hours. For starting the petrol motor these cells are connected to the dynamo by a switch; the petrol motor is in this manner started by the driver from his seat, and when it is running these cells are always connected across the terminals of the dynamo, and in this way tend to keep the speed of the petrol motor constant, receiving current from the dynamo when more current is generated than is being used by the electric motors, and supplementing any demand for curren made by the latter over and above that being generated at t moment. A combined ammeter and voltmeter is fitted in seat to the left of the driver. The voltmeter is at all ti connected across the dynamo terminals, and the ammeter can e be switched over to show the quantity of current being gene or to show the amount of current being taken by the mo two-way switch being provided for this purpose.

The main frame of the Fischer 'bus is supported at f rear by semi-elliptical springs, those in front being carri end by a transverse spring passing beneath the frame, the ends being fixed to the frame in the usual manner. axle is built up like a girder, carries the steering he end, and has the front springs which are bolted to i that they pass through between the upper and the l of the girder. The steering is effected by a hand w the top of a long vertical shaft, which terminates in a pinion operating a rack. The steering wheels the Ackermann principle, the rack just mentione to them by a rod in much the usual man

illustrated, the hand wheel has to be moved to the left when the vehicle is to be steered to the right, and *vice versâ.* The wheels are of the artillery type, and have 101·6 mm. (4 in.) Calumet tyres. The front wheels are 96·5 cm. (38 in.) in diameter, and the rear wheels 116·8 cm. (46 in.). A sand box with handle control is now fitted, the sand being led through tubes to points in front of the driving wheels. The total weight of the vehicle is nearly four tons. Brakes of the spoon pattern are fitted to the tyres of the rear wheels, and are connected with a hand lever beside the driver. These are only intended to be used in case of emergency, or for holding the vehicle when at rest on a hill.

The Fischer petrol-electric lurry resembles the omnibus on the same system above described. Its chief dimensions are: Length, 5·5 m. (18 ft. 4·5 in.); useful width of platform, 1·52 m. (5 ft.); width of hubs, 2·28 m. (7 ft. 6 in.); and wheel base, 3·2 m. (10 ft. 6 in.); the front wheels are 91·4 cm. (3 ft.) in diameter, and the rear wheels 106·7 cm. (42 in.); they are fitted with 17·8 cm. (7 in.) Calumet solid tyres. The machinery differs somewhat from that on the omnibus, the motor being of the four-cylinder balanced horizontal type, instead of having three vertical cylinders. The bore is 139·7 mm. (5·5 in.), and stroke 152·4 mm. (6 in.). The crank-shaft is coupled direct to a 9-kilowatt dynamo, which runs at a normal speed of 500 revolutions a minute, and gives 110 volts at that speed. The current from the dynamo passes direct to two motors, each of which is connected by double reduction spur gearing to one of the rear wheels, the balance passing to or from a comparatively small battery of accumulators according as more or less power is required by the motors than is being furnished by the dynamo. The controller, which has five speeds forward and also five-speed reverse, acts as in an ordinary electrical vehicle, and makes the necessary connections between the accumulators and motors. The dynamo terminals are normally connected directly to the terminals of the cells. The battery consists of forty-four cells, having a capacity of 136 ampère-hours at a three-hour rate of discharge. On the level the vehicle travels at speeds up to 7·7 km. or 8 km. (4·5 or 5 miles) an hour with its full load. It has been stated that the motors are capable of standing an overload of 150 per cent., that the vehicle can ascend grades of 15 per cent. with a load of 7½ tons, and that the fuel consumption per ton works out at ⅝d.

The motors, gearing, and axle of this lurry are entirely enclosed in a dust-proof casing, which can be removed easily in order to get at the mechanism. The motors themselves are entirely independent of one another, and each carries a pinion on the inner end of its shaft, the pinions gearing with spur wheels mounted on an intermediate shaft from which other pinions transmit the power to spur wheels mounted about the rear axle and connected with each of the side wheels. Both front and rear axles are strongly built; the main frame is mounted above the former on springs of the platform type, and above the rear axles on semi-elliptic springs, having freely sliding ends. The rear axle is connected to the frame by distance rods in much the usual way.

Some particulars of a later type of Fischer one-ton truck or lurry may here be given.

In this the engine is again three-cylinder, and it is capable of developing 10 h.p., and normally gives about 7 h.p., at a speed of about 600 revolutions per minute. Its power and speed are regulated by varying the time of ignition and by a throttle-valve. The throttle-valve is provided with a magnetic control, the solenoid of which is arranged in series between the dynamo and the accumulators. By this arrangement the speed of the engine is to a certain extent automatically governed, and the quantity of current supplied by the dynamo to the cells is kept constant. A fan is fixed on the rear end of the crank-shaft, and a circulating pump is friction-driven off the flywheel. The multipolar dynamo is coupled direct to the front end of the crank-shaft, and therefore lies beneath the floor in front of the seat. The engine and dynamo are fixed on a common bed plate, which is in turn secured to cross-members of the main frame. The dynamo has an output of 5 kilowatts, and its normal E.M.F. is about 110 volts, there being 50 cells arranged in series to form the battery. The accumulators are of the P.V. chloride type, and have a capacity of about 67½ ampère hours at a three-hour rate of discharge. The petrol engine normally charges them at the rate of 50 ampères, and the maximum discharge rate may be something like 150 ampères for short periods on exceptionally steep hills.

The rear axle is divided centrally, and each half is carried in two bearings in a substantial framework. No differential gear is needed, as two separate series motors are employed, one of which drives each half-axle. The inner ends of the half-axles carry spur wheels, and corresponding pinions on the motor shafts mesh with them. The output of each motor is 2½ kilowatts; they are series wound. The connections which are made by the controller between the accumulators and the motors give five forward speeds besides reverse speeds. In the first forward notch the motors are put in series with one another, and a resistance is introduced in the circuit. In the second notch the motors are still in series, but the resistance is cut out. In the third position the fields are in parallel, with one another, and the armatures in series with each other and with them. In the fourth notch the armatures are in parallel, and the fields in series with one another and with the armatures. In the fifth position the two motors are in parallel with one another. For starting the petrol motor, the accumulators by means of a switch are connected with the dynamo through a resistance; after starting the resistance is, of course, cut out. An ammeter and voltmeter are fixed beside the driver. The vehicle is strongly built, and weighs a little over three tons. The front axle is of a built-up girder construction, and resembles those on other Fischer vehicles. The tanks are arranged behind the driver's seat, and the seat itself is at a considerable height above the ground.

A very much larger Fischer truck than the above has run from London to Liverpool, *viâ* Derby and Manchester, completing the 352 km. (219 miles) in very bad weather without any breakdown. The truck is intended to carry loads as much as 10 tons, and is geared to speeds up to 4 miles an hour. The average speed maintained on the trip was 3·4 km. (2·125 miles) an hour, and the fuel consumption for the journey worked out at 5·1 l. (9 pints) per mile. This truck is fitted with a 22-h.p. petrol motor and a 9-kilowatt dynamo. The battery consists of 48 cells, having a capacity of 150 ampère hours. Two 7½-h.p. electric motors drive the rear wheels. The vehicle is 5·5 m. (18 ft. 4 in.) long over all, and has 17·78 cm. (7 in.) solid rubber tyres.

The City and Suburban petrol-electric car is, to a certain extent, an experimental vehicle, though it has given good performances: later cars, however, are to be of considerably greater power. It is a four-seated double phaeton, and the back seat has a hood. The battery is fitted underneath the rear seat in a compact "boot"; it consists of 44 small cells of 70 ampère-hour capacity. The chassis itself consists of two framés, an upper one of channel steel carrying the battery box, the car body, the dynamo or generator, and the petrol motor. This upper frame, which as it were forms a chassis in itself, is mounted by double elliptical springs on the lower tubular framework, which is practically identical with that employed in the electric broughams of the same make; that is to say, it consists of front and rear axles connected by jointed tubular reaches, the electric motors which drive the car being mounted on the rear axle, and driving the rear wheels by means of pinions which engage with protected gear rings rigid with the wheels. The outer periphery of these gear rings forms the brake drums, on which work hand-operated compensated band brakes. Additional brakes acting on the motor shafts are under the control of a pedal immediately under the driver's seat, the first movement of which cuts off the current, while further depressing it applies the brakes.

The 5½-h.p. twin-cylinder Daimler petrol motor is set longitudinally in front under a bonnet, as in most petrol cars; ignition is high tension electric, and the governor is ordinary. It is controlled by two handles mounted one each side of the raked steering pillar immediately below the steering wheel, one of these hand levers advancing or retarding the spark, and the other acting as accelerator by operating upon the governor spring. The petrol motor shaft lies longitudinally, and is coupled to a four-pole 5-h.p. dynamo fixed in the position usually occupied by the change-speed gear. The coupling is made by bolting the male member of the old clutch to the female portion so as to form a flexible coupling between the dynamo and the petrol motor. Dynamo, electric motors, and batteries are, as in the Fischer omnibus, all in parallel with one another, the battery thus acting as a flywheel, and taking up energy from the dynamo when the load on the car is small, and assisting the dynamo to drive the motors when the load on the car increases. Ordinarily, when running on the flat, the output of petrol motor and dynamo is greater than the amount of current required by the motors to drive the car, and the batteries consequently receive a charge. Going up hill, however, as the load increases, the battery supplies current to the motors, and as these latter are capable of withstanding an overload of upwards of 100 per cent. for a moderate period, more than 12-h.p. is under such circumstances available, the motors being rated at 3-h.p. each. As the weight of the vehicle is considerably less than that of an ordinary electric car of the same size, its hill-climbing powers are highly satisfactory. The batteries are capable of running the car without the assistance of the petrol motor some 32 km. (20 miles) on the level.

To re-start the engine and dynamo does not involve manual effort. A small starting resistance with a number of contacts is mounted on the dashboard, the dynamo is switched on to the cells, the resistance being in its armature circuit, and it then starts as an electric motor. As its speed increases, and the petrol motor takes its explosions, the resistance is cut out gradually, and the dynamo then acts as a generator and supplies current to the battery and motor circuit.

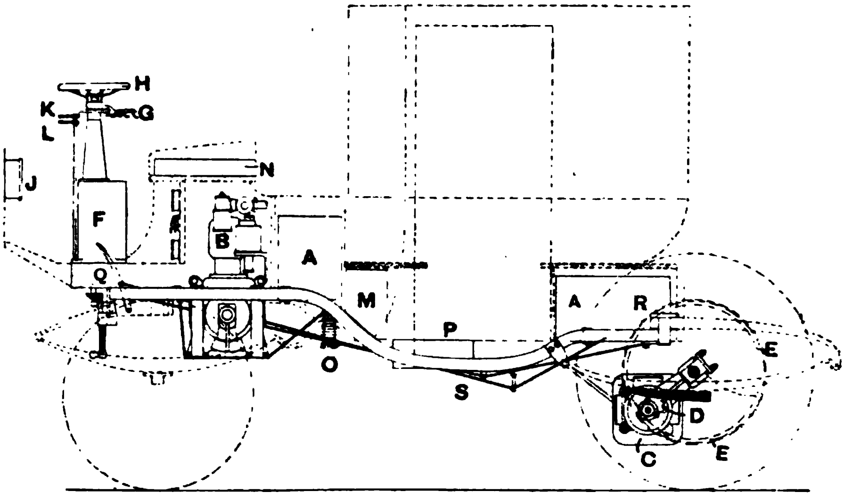


Fig. 776.—Diagram of Mildé Petrol-Electric Car.

The methods of controlling the motors are identical with those employed in the City and Suburban electric broughams; a horizontal cylindrical controller mounted under the driver's seat is operated by a side lever projecting upwards through the woodwork of the seat between the cushions. A main switch plug is also provided on the top of the seat, the removal of which renders the starting of the car impossible. The steering differs, however, by the substitution of an inclined steering pillar and wheel for the tiller usual on the electric broughams. The different positions of the controller group the motors so as to give three speeds, while reversing is effected in the usual way

by a change-over switch. This car is stat
practically a non-stop run of 128 km. (8(
to be built on the same principle will ha
petrol motors and corresponding dynamc

The Mildé petrol-electric four-seate(
not exceed that of an ordinary electı
daily 10-hour journey of 250 km. (40
de Dion-Bouton 6 or 9-h.p. petrol m(
driver's seat, and drives a dynamo givi
100 volts ; petrol motor and dynamo
(330 lb.). A battery of accumulators,
weighs 450 kg. (990 lb.), and there is
suspended from the rear axle and dri
rings secured to the rear wheels by n
extended motor shaft. Part of the dyn
to the motor, and the surplus or remain
which come into use when ascending h
motor is stopped for short distances th
direction are governed by a controller as
The battery is of 107 ampère hour capaci
rate.

The scheme of the Mildé petrol-electri
the diagram, Fig. 776, in which A indi
B the petrol motor and dynamo, C the el
D driving the toothed ring E on the rear
operated by handle G under the hand s
ammeter and voltmeter, K the handle gc
of the explosive mixture, L the ignition
tank containing the motor cooling water, N
radiator, P the exhaust silencer, and Q the
on the rear wheels through rods S.

An alcohol-electric car, run by Kriéger
trials, 1902, weighed complete 1,320 kg. (
Kriéger motors on the front wheels, its
Phœnix cells, weighing 400 kg. (882 lb.). A
motor was coupled to a four-pole shunt
continuously charge the cells, and to supp
propel the vehicle at 15 km. (9·32 miles)
travelling at that speed the cells are not

At any speeds in excess of that, or when climbing hills, the battery furnishes the excess current needed.

The Munson car is an early petrol-electric vehicle, made by the Munson Electric Motor Co., of La Porte, Indiana, U.S.A. Its petrol motor has two cylinders and equilibrated cranks directly driving a dynamo, whose ring armature is of large diameter, so as to act as a fly wheel for the petrol motor. The armature has a double winding and a disc collector. The field magnets have six poles excited by a single fine wire coil, and are electrically divided into two parts respectively connected to each of the two batteries of accumulators, so that the coupling of these two batteries does not alter the excitation of the dynamo; this is in a closed gear case. By aid of the controller the batteries can be connected in series or shunt, this giving the motor two speeds. A mechanical change of speed in the ratio of 1 to 4 gives a total of four speeds. Hospitalier remarks that for two of these speeds the petrol motor turns at only half speed, and consequently at half power, and that in such circumstances its employment must be unsatisfactory. Reverse motion is given by a special position of the coupler.

CHAPTER XX

MOTOR BICYCL

ATTEMPTS to drive bicycles by petrol ı
frames have numbered legion, and at th
considerably more than a hundred types
market; but yet this vehicle is still in
stage, and a great deal remains to be do
will even approach perfection. However,
backs, many of the machines are quite se
really hard work.

The advantages of the motor bicycle ove
can be chosen more easily, as only a single
is more perfect, and the machine is so
taken in and out of traffic and to be r
inaccessible to the car or even voiturette.
and the one which designers are endeavo
liability to skid on greasy roads, but impro
better distribution of weight are doing muc
also it must not be forgotten that much o
slipping attributed to bad construction a
riding, and it is necessary, if these incident
the rider keep a firm grip of the handl
perfectly. It is difficult to design a motor bi
and limited space available for the distribu
and the difficulty is increased by the neces
motor relatively to the driving wheel. That t
real is shown by the indecision amongst m
correct position of the motor, which until las
in every possible way, whilst the drive was l
friction devices, or toothed gear, and the r
front wheel, back wheel, or a crank pin. At
attempt to standardise practice.

As regards history, a motor bicycle was c in 1885, but it was not until nine or ten years later that any development of this application of motor driving occurred. The Wolfmuller motor bicycle (Fig. 777) appeared in 1894, but it was hardly a practicable machine. It had two parallel motor cylinders, and the bicycle framework had four horizontal inter-connected tubes and four inclined tubes, similarly arranged. The rear wheel was solid, and had a pneumatic tyre, and acted as the motor fly-wheel. Motion was transmitted by rods from the two trunk pistons, reciprocating in unison with each other, to cranks on the rear axle, ball bearings at both ends rendering it possible for the rods to move in the oblique direction necessitated by the relative positions of the motor cylinders and rear axle crank pins.

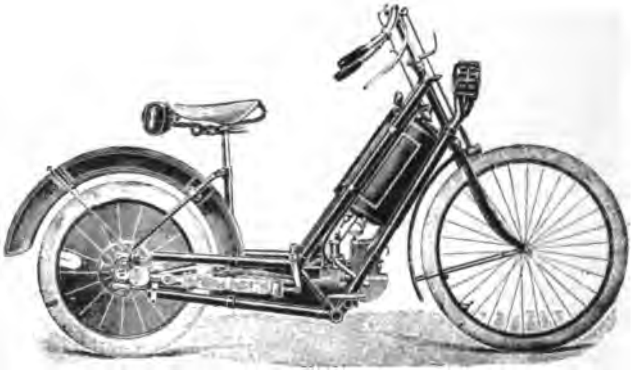


Fig. 777.—Wolfmuller Motor Bicycle.

The modern bicycle motor has a power in the neighbourhood of 2-h.p., is air cooled with a few exceptions, has one cylinder except in two or three cases where two cylinders are made to form an angle of 30° or 40° with each other, and its position has been so far settled that in the majority of machines it is now within the frame, on or under the lower frame tube, or made into the frame at the bottom bracket, or at any rate so mounted that it serves to stiffen the frame. Exceptions are the mounting of the motor behind the seat pillar tube, or in one of the wheels, as in the Singer and one or two French makes. When the motor is bolted or clipped to one tube only, it imposes twisting strains on the tubes, and tends to weaken the whole frame; but it is fair to state that this practice has given satisfaction so far. The use of Bowden wires for operating the various parts is effecting an improved appearance. Both pipes and wires are being made shorter and more direct, and as far as possible they are hidden, but without making the frame tubes serve as their casings. Exhaust valve lifters are superseding compression relief cocks, and by interconnecting the various regulating devices (particularly exhaust lifter and ignition cut-off switch) many can be operated by a single lever. For ignition, the trembler is being superseded by the single make and break contact whose commutator coil frequently has its own trembler attached to it. There is a movement to employ mechanically operated inlet valves; and the Minerva motor (p. 280) and the Weller motor have this feature. Lubrication has become more reliable; oil force-pumps are perhaps more usual, but an alternative is a special form of sight-feed lubricator. Float-feed spray carburetters are used chiefly, the transition from surface carburetters being comparatively recent. On the motor inlet pipe is a throttle valve regulating the quantity of mixture supplied; and in very many cases this is the only method of regulation, the retarding of ignition becoming automatic with the lower compression in the cylinder. The method of driving in the majority of cases is by belt from the motor pulley to a pulley secured to the rims of the back wheel. Chains are not considered sufficiently flexible, although some makers have used them with success, but have had to employ spring devices to avoid the risk of the chain snapping.

Motor bicycle frames have become more substantial, and in many cases additional cross tubes increase the rigidity. Great strain is imposed on the steering heads, particularly near the crown of the front forks, and so these parts are being made much stronger; the greater the weight of the cycle and the make of the forks, the stronger must be the head. Cycles for heavy riders should have additional stays between the bottoms of the forks and the top of the head. The practice of having the bottom of the frame in front of the motor formed of a curved tube terminating in a right angle bracket, from which a single straight tube also passes, is believed to be a violation of the principles of cycle design. Again, rear forks have often to be bent into four right angles to effect a clearance from the belt, and this is a point of weakness. The tread—the overall width of the bottom bracket axle—varies considerably, and the greater its width the greater the strains imposed on the bottom bracket when pedalling, and suitable provision for this should be made; there is perhaps, a tendency to construct that portion supporting the bottom bracket of too slight material; apart from the aspect of strength, the narrower the tread the easier pedalling becomes, but when the pedals are used as foot rests merely the wider tread gives more comfort.

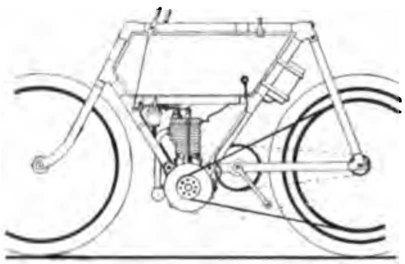


Fig. 778.—Werner Motor Bicycle.

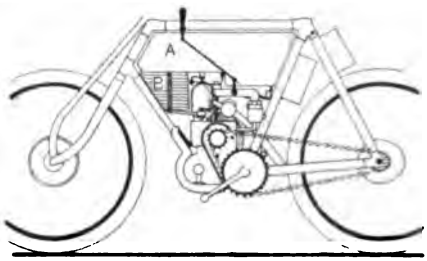


Fig. 779.—Royal Enfield Motor Bicycle.

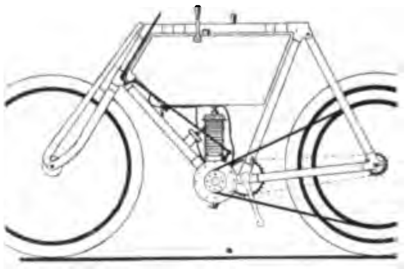


Fig. 780.—Bradbury Motor Bicycle.

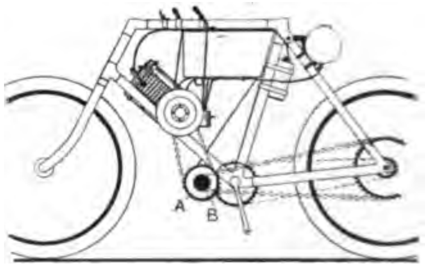


Fig. 781.—Bradbury Motor Bicycle, Model C.

The new Werner bicycle (Fig. 778) is the first example of bicycles with the motor forwards of the bottom bracket: it has its bottom bracket in a new position, and the motor forms a part of the frame. There is a belt drive to the back wheel. The carburetter is of the spray type. The Minerva has the motor with mechanically operated inlet valves, described on p. 280; it is clipped to the lower frame tube well down, its crank case being mostly below the bottom bracket. There is the usual belt drive.

The Royal Enfield (Fig. 779) has a water-cooled motor, and a single chain transmits power from the motor sprocket and bottom-bracket, foot-propelled sprocket to the back wheel. The motor sprocket is on a shaft driven by spur gearing from the crank-shaft

at lower speed. The lower frame tube foi
motor, which is secured by six bolts. 1
internal spring devised to give the nece
is a free-wheel clutch between the botto
sprocket mounted upon it. A further fr
wheel hub gives a free engine when req
shown at A; the water from the motor
aluminium tubular coil radiator B.

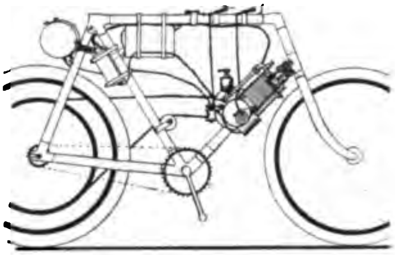


Fig. 782.—Clement-Garrard Motor Bicycle.

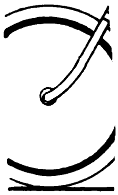


Fig. 7

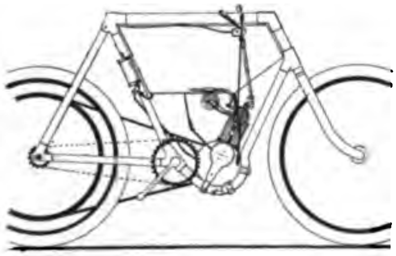


Fig. 784.—Quadrant Motor Bicycle.

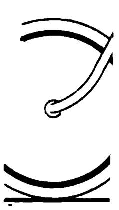


Fig. 7

The Bradbury is in three designs, the
by Fig. 780. The crank chamber of the
combined with the bottom bracket casti
straight. Another design has an inclined 1
side of the lower front tube, and the belt d
standard model; a detachable back seat
model (Fig. 781) has a light Clement-Garr
shown. The motor chain drives a sprocket
fixed to A, chain drives the back wheel.

The Clement-Garrard (Fig. 782) has a

a jockey pulley being introduced into the belt drive. The same arrangement of parts is kept when a twin cylinder motor is employed; the two cylinders form an angle of about 30° with each other. A third model resembles one type of Bradbury bicycle (Fig. 781), a two-speed gear being introduced at A. The Fabrique National (F. N.) carries the motor centrally inside a hoop formed in the front tube (*see* Fig. 783). To reduce the width, the exhaust valve is in front instead of at the side of the motor. In the Humber bicycle, the motor forms part of the lower front tube, as described on p. 282. The Quadrant (Fig. 784) carries the motor in a looped frame in front of the bottom bracket, and there is a belt drive. A single lever works the main switch, lifts the exhaust valve, regulates the mixture, and times the ignition. Other machines with looped frames are the Canada, Clarendon, Clyde, New Century, Kerry, and Calvert.

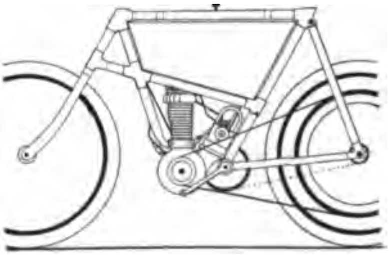


Fig. 786.—Altena Motor Bicycle.

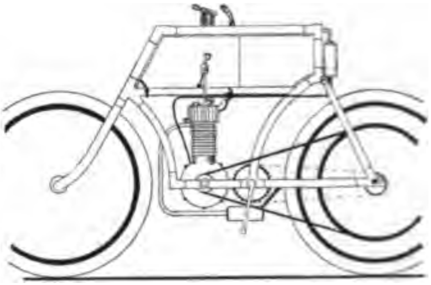


Fig. 787.—Royal Sovereign Motor Bicycle.

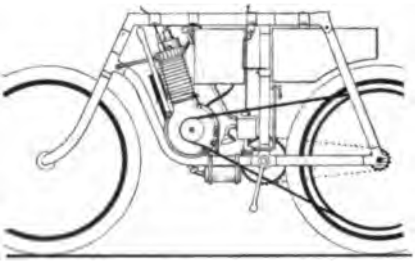


Fig. 788.—Orient Motor Bicycle.

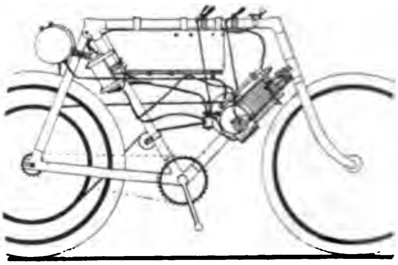


Fig. 789.—Osmond Motor Bicycle.

The Morris (Fig. 785) frame is given a peculiar shape to accommodate the motor; the Lincona belt is prevented from slipping by special grip pulleys. The Altena (Fig. 786) has an X-frame; the magneto ignition allows of great simplicity. The 2-h.p. vertical motor is governed entirely by twisting the handles. The Royal Sovereign (Fig. 787) has an additional bearing for the motor crankshaft outside the driving pulley. The carburetter is of the surface type. The Orient (Fig. 788) has a large motor well forward, and the flat leather belt runs over a jockey pulley. The Osmond belt-driven bicycle (Fig. 789) has a small motor, also well forward; this is one of those machines in which the motor is but an auxiliary means of propulsion. The two-speed chain-driven machine is practically identical with one type of Clement-Garrard and Bradbury machine (Fig. 781).

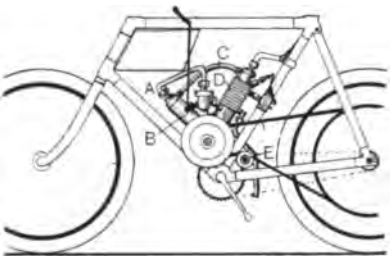


Fig. 790.—Bichrone Motor Bicycle.

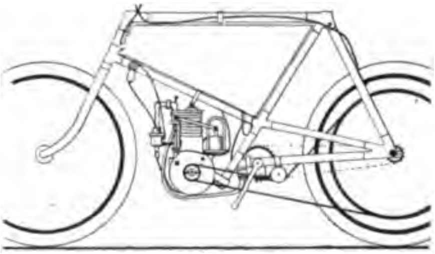


Fig. 791.—Davison Motor Bicycle.

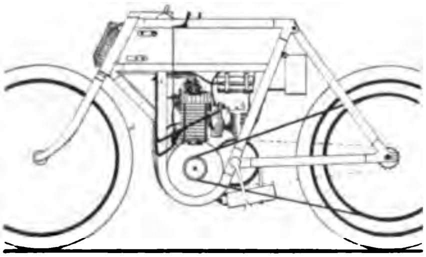


Fig. 792.—Jesmond Motor Bicycle.

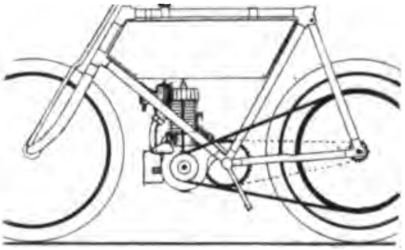


Fig. 793.—Weller Motor Bicycle.

The Bichrone two-stroke-cycle motor is fitted into the angle made by the lower frame tube with the seat tube above the bottom bracket (*see* Fig, 790). In this motor the explosive mixture enters from the carburetter at A, is compressed in pump B, and forced through C to the motor cylinder D. There is a belt drive to the rear wheel over the jockey pulley E. The exhaust pipe, but not the silencer, is shown.

In the Davison (Fig. 791) the frame is of peculiar shape, and the motor is clipped to an extension of the seat pillar tube and to the slanting tube above it. The bottom bracket is a malleable casting which slips over the tube passing from the motor to the lower back forks. The spray carburetter is actually a mixing valve. Gauge glasses are fitted to both petrol and lubricating oil tanks. The Jesmond (Fig. 792) has a vertical motor whose head is water-cooled, the cylinder walls having the usual radiating ribs. The radiator is in front of the head, and water circulation is natural. The frame is of peculiar shape. In the Royal (American) the seat pillar tube branches into four thin tubes, which are again connected together beneath the motor, being received in sockets in the bottom bracket casting. A mixing valve replaces the ordinary carburetter. The Weller (Fig. 793) has a looped frame and the motor is low down. Inlet valves are operated mechanically. In the Crypto (Fig. 794) the lower frame tube is connected by the motor crank chamber to the bottom bracket. The Bat bicycle (Fig. 795) has no pedals, but

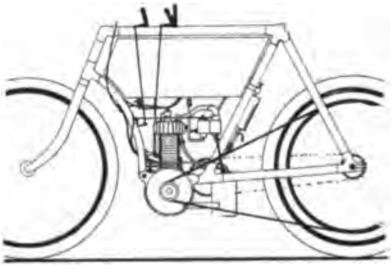


Fig. 794.—Crypto Motor Bicycle.

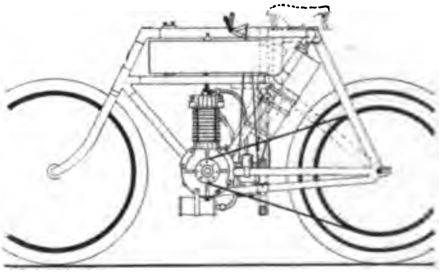


Fig. 795.—Bat Motor Bicycle.

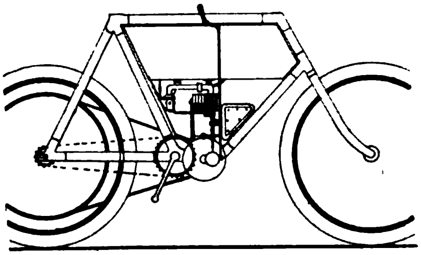


Fig. 796.—Robinson and Price Motor Bicycle.

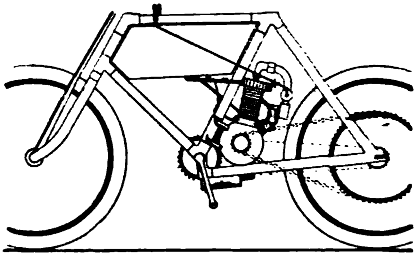


Fig. 797.—King Motor Bicycle.

foot rests are fixed to the frame betwe
wheel. The position of the motor and
of the frame are clearly illustrated.
the saddle, which is kept in its normal
with the object of absorbing vibration
In the Rex bicycle, the motor is in the
but the frame is shaped to embrace the

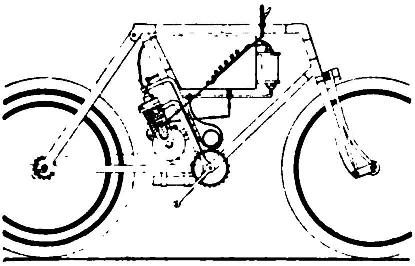


Fig. 798.—Celeripede Motor Bicycle.

Fig.

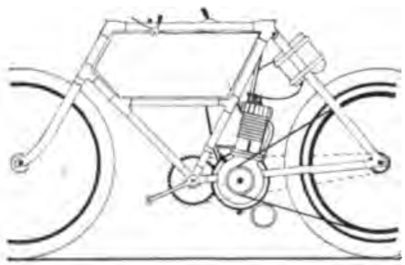


Fig. 800.—Hamilton Motor Bicycle.

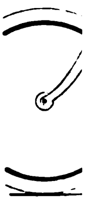


Fig.

belt drive. In the Gamage the motor f
the Diamond frame; the seat pillar tub
the rear fork are fixed to it. The carb
inlet valve; such a device is the Carlt
Robinson and Price (Fig. 796) has the
the bottom bracket formed of one castin
the motor is supported above the back l
the seat pillar tube. There is a chain dr
ring on the back wheel, a spring devic
flexibility. The Celeripede (Fig. 798) ha
the seat pillar tube. The front forks ar

wheel spindle by links held approximately horizontal by a compression spring between the crown of the forks and two trussed levers, which connect the two links together and cause the spring to act equally on both. The Ormonde (Fig. 799) has the motor behind the seat pillar tube and there is a belt drive. In the Hamilton (Fig. 800), the motor, nearly vertical, is fitted into the back lower fork, between seat pillar tube and rear wheeel. The Mersey has a vertical water-cooled motor whose steel crank chamber is carried in a U-shaped cradle formed just behind the bottom bracket. The water-jacket forms a spiral. A friction clutch between motor and rear wheels allows of a free engine. Gearing on the motor drives at reduced speed a small sprocket which chain-drives a large sprocket on the back wheel.

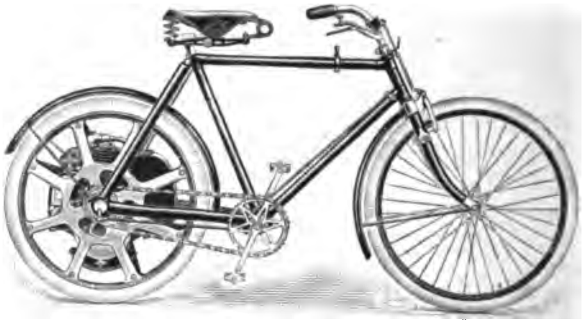


Fig. 802.—Singer Motor Bicycle.

The old Werner style of having the motor in front of the steering head over the front wheel has now almost entirely disappeared. The Quand-Même and Ixion bicycles have two-stroke cycle motors mounted in front of the steering heads, and a smooth friction roller (the Ixion is rubber covered) is in driving contact with the tyre of the front wheel. The motor can be raised or lowered at will.

The Princeps (Fig. 801) is an example of how a two-cylinder motor may be placed. The drive is either by chain or belt. Other makes of machines with similar motors have them well forward on the lower frame tube.

The Singer machine (Fig. 802) is of the "motor wheel" type, the motor being entirely within the rear wheel. Aluminium is largely used to give lightness in the construction of both wheel and motor. The Singer motor wheel which is employed on the bicycle just mentioned and on the tricycle mentioned in Chapter XVIII. (*see* p. 576), is illustrated in detail by Fig. 803; and the following explanation of the letter references will make the construction clear: A is the carburetter, B its filling plug, and C its emptying tap; D is the adjustable atmospheric lever, E crank case, F its lubricating plug, and G its emptying plug; H is a cap covering axle end; I, cylinder; J, exhaust box or silencer; K, valve chamber;

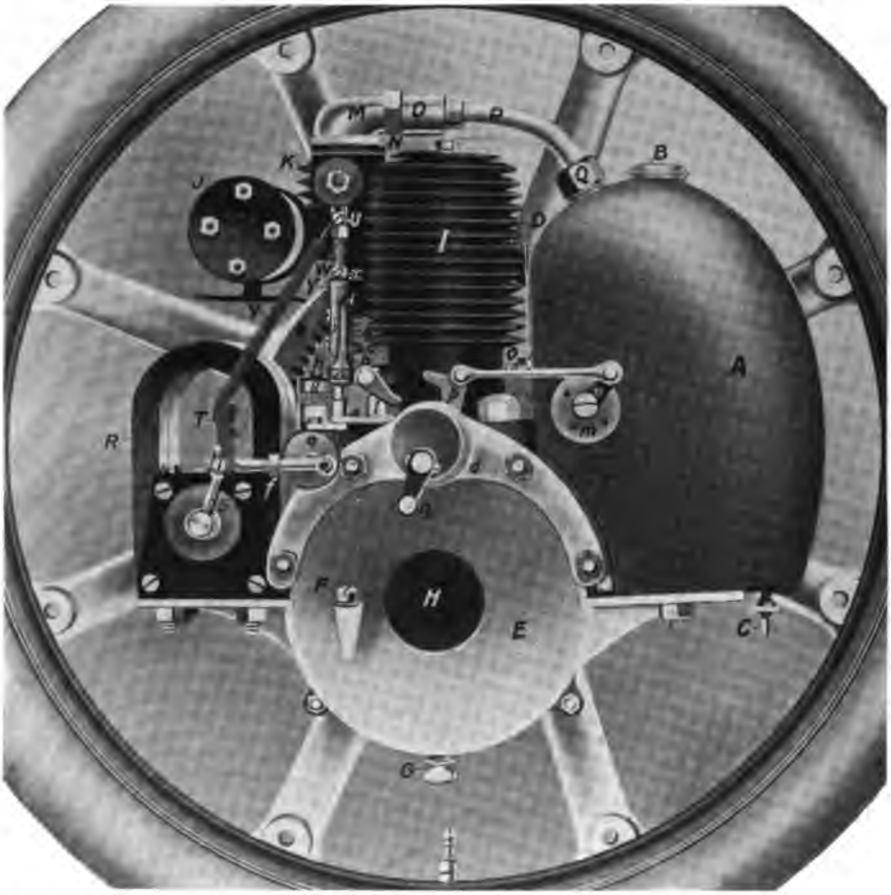


Fig. 803.—Singer Bicycle Motor, Carburetter, etc.

L, ignition plug; M, detachable dome over valve chamber; N, detachable inlet valve and seating; O, union containing separator between supply pipe and dome; P, supply pipe; Q, union between supply pipe and carburetter; R, magneto machine for ignition; S, magneto lever; T, magneto terminal; U, terminal on brass interrupter guide; V, insulated wire connection; W, interrupter stalk and coil spring; Y, screw for holding interrupter to vertical insulated block; Z, internally toothed wheel; *a*, exhaust valve spring; *b*, exhaust valve lifter; *c*, cup, with cotter below, holding exhaust valve spring; *d*, trunnion; *e*, cam working magneto machine and interrupter gear; *f*, adjustable connecting rod between cam and magneto machine; *g*, exhaust cam box, containing bush and part of cranked exhaust cam plunger *h*; *i*, insulation; *j*, vertical insulated block: *k*, interrupter footpiece with roller at end engaging cam *e*; *l*, detachable bracket and guide for interrupter gear: *m*, supply valve cover; *n*, lever to regulate supply valve; *o*, connecting rod between supply valve and double action lever *p*; *q*, external lever connected by rods to the handle-bar; *x*, collar for adjusting interrupter.

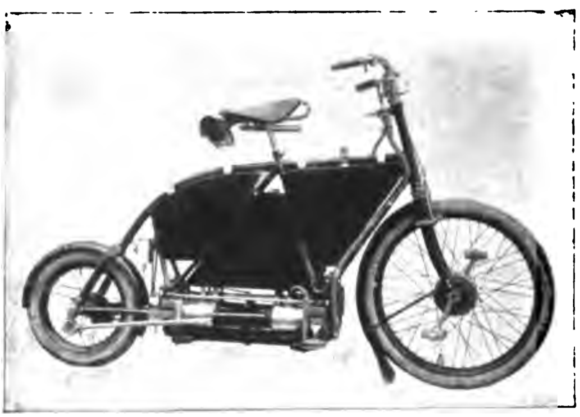


Fig. 804.—Holden Motor Bicycle.

The Singer chain-driven machine has the motor in the same position, but the sprocket on the right end of the motor shaft chain-drives a sprocket at the bottom bracket. A hollow shaft or spindle runs through the bracket, and on its other end is a chain wheel which drives the rear road wheel, on which is a special spring buffer chain wheel and a free-wheel clutch. To one form of Singer machine with motor wheel in front an extra saddle can be fitted at the rear, it being supported by additional forks and ties; stationary foot rests for the passenger are clipped to the horizontal forks.

The Holden bicycle (Fig. 804) is the only remaining one of the vast number of motor bicycle arrangements not yet mentioned that calls for special remark. The Holden bicycle shows great originality of design, the four-cylinder motor driving the rear wheel direct, and being water-cooled. The front wheel is of the Crypto geared type, and the rear wheel is smaller than usual. The motor forms a part of the frame, and is placed very low, and on each side of it is a foot rest, the pedals on the front wheel being for occasional use only; indeed, it is probable that these pedals will not be used on future models. The Holden machine is novel, and is said to have given very satisfactory results. Its electric ignition system is referred to on p. 183.

CHAPTER XXII.

TABLES GIVING RESULTS OF AUTOMOBILE TRIALS, EFFICIENCY TESTS, AND RACES.

PERHAPS the most satisfactory way of presenting a comprehensive yet succinct record of what the automobile already has accomplished on common roads, is to tabulate briefly the results of the various trials and races that have been held under the auspices of such influential bodies as the automobile clubs of France and England, the Liverpool Self-propelled Traffic Association, and other approved authorities. The data for the tables which constitute this chapter are taken from various sources, most of them official, and special acknowledgment must be made of the help afforded by the columns of the *Automotor Journal* in this direction. The events here recorded range over a period of very nearly ten years, between July, 1894, and September 1903, and include the following races:—Paris-Amsterdam, 1898; Paris-Berlin, 1901; Paris-Bordeaux, 1895, 1899, and 1901; Paris-Dieppe, 1897; Paris-Madrid, 1903; Paris-Marseilles, 1896; Paris-Rouen, 1894; Paris-Vienna, 1908; Gordon-Bennett, 1903; and Nice-Castellane, 1899; the following trials held in Great Britain:—Richmond, 1899; Liverpool, 1898, 1899, and 1901; Cromer, 1902; Dashwood Hill, 1902; A. C. G. B. Reliability Trials, 1900 to 1903: Tyre trials, 1902; the following French events:—Town and Suburban Vehicle trials, 1898, 1899, and 1902; Suresnes-Corbeil consumption Trials 1902, and 1903; Tour de France, 1899; Versailles Heavy Vehicle trials, 1897 and 1898; alcohol consumption trials, 1901 and 1902; a number of Circuits, 1902; consumption trials, 1902; and the Château-Thierry and Gaillon hill climbs, 1902; one German event, the Leipzig-Eisenach consumption trials, 1902; and a number of American brake tests, hill climbs, trials, and non-stop runs, 1895-1902.

The tables are arranged in chronological order as far as considerations of space allow, and the index, which begins on p. 812 will be found a ready means of disclosing the whereabouts of any particular table should the reader fail to find it by means of the above arrangement.

CHICAGO TRIALS, NOVEMBER, 1895.

Constructor of Vehicle.	Type of Motor.	Weight on Driving Wheels.	Weight on Steering Wheels.	Total Weight.	Number of Cylinders.	Bore of Cylinders.	Piston Stroke.	Horse-Power of Motor.	Horse-Power available at Wheel Tyres.	Horse-Power absorbed by Transmission Gear.	Percentage of Power Yielded by Transmission Gear.	Consumption of Petrol Spirit (density ·688) per hour.	Consumption of Petrol Spirit per useful horse-power hour.	Kgm. at Wheel Tyres given per kg. of Petrol Spirit.	Speed per hour.
Petrol.		kg.	kg.	kg.		cm.	cm.					kg.	kg.		km.
De la Vergne	Benz	570	195	765	1	12·8	16·5	1·41	0·7	0·71	50	1·47	2·94	58·7	11·23
								2·97	1·57	1·4	53	2·02	1·29	96	18·36
Duryea	Duryea	330	222	552	2	10	11·25	1·69	1·1	0·59	65	1·82	1·65	75	7·92
								1·75	1·16	0·59	65	1·7	1·47	85·5	7·99
Haynes and Apperson	Clerk	378	191	569	2	10	10	0·87	0·26	0·61	30	2·62	—	12·5	6·84
								2·23	0·95	1·28	46	2·6	2·74	45	7·27
Lewis	Lewis	408	354	762	1	12·5	12·5	1·06	0·53	0·53	50	1·49	2·8	43·9	6·48
								0·9	0·25	0·65	28	1·48	5	21·3	9
Macy—Roger	—	655	174	829	1	12·5	17·5	2·31	0·33	1·48	36	1·46	1·77	70·6	9·36
								5·18	2·5	2·68	48	2·22	0·89	140	17·28
Mueller	Mueller-Benz.	570	174	714	1	13·75	15·6	1·46	0·69	0·77	47	1·75	2·54	48·6	9·86
								3·75	2·18	1·57	58	1·54	0·71	175	18

Constructor of Vehicle.	Type of Motor.	Weight on Driving Wheels.	Weight on Steering Wheels.	Total Weight.	Horse-Power of Total Electric Energy Yielded.	Accumulator Discharge.		Horse-Power of Motor.	Horse-Power Available at Wheel Tyres.	Horse-Power absorbed by Transmission Gear.	Percentage of Power Yielded by Transmission Gear.	Kilowatts of current used per useful horse-power per hour.	Kgm. at Wheel Tyres given per kilowatt hour of current.	Speed per hour.
						Volts.	Ampères.							
Electric.		kg.	kg.	kg.										km.
Morris and Salom	Lundell	572	177	749	1·36	97	10·5	1·12	0·78	0·34	70	1·74	15·45	18·72
					2·9	96	22·5	2·46	1·78	0·68	72	1·63	17	36·72
Sturgos Electric Motocycle Co.	Lundell	946	665	1,611	0·99	35	21	0·62	0·41	0·21	66	2·42	11·2	6·73
					1·94	69	11	1·53	1·14	0·39	74	1·7	15·8	16·2

POIDS LOURDS (HEAVY VEHICLE TRIALS) VERSAILLES, 1897 AND 1898.

Year.	Vehicle.	Horse-Power of Motor.	Revolutions per Minute.	Number of Passengers.	Normal Speed per hour.	Useful Load.	Dead Weight.	Total Weight.	Weight per Horse-Power.	Adherent Weight when fully loaded.	Percentage of Adherent Weight to Total Weight.	Consumption of fuel per kilometre-tonne.		Water.
												Total.	Useful.	Coke.
					km.	kg.	kg.	kg.	kg.	kg.				
	Steam.											*Coke.* kg.	kg.	
1897	De Dion-Bouton Omnibus	25	600	16	14 to 14·5	1120	5040	6160	235	4200	0·68	0·31	1·73	6·2
1898	,,	30	600	20	14·5	2000	6380	8380	276	5200	0·51	0·321	1·33	4·87
1897	De Dion-Bouton Tractor and Trailer	35	600	35	10 to 10·8	2500	7410	9910	274	6051	0·61	0·37	1·42	5·5
1898	,,	30	600	34	13·8	2400	6200	8600	283	6260	0·73	0·34	1·2	4·98
												Petroleum. l.	l.	
1898	Serpollet Omnibus	15	415	14	12·3	1350	5500	6850	442	4450	0·65	0·245	1·207	13
1898	Leyland Brake	6	—	7	9·5	750	1950	2575	276	1565	0·6	0·6	1·08	11
	Petrol.											*Petrol Spirit.*		
1897	Panhard and Levassor Omnibus	12	750	14	10 to 15	1000	2400	3400	273	2300	0·68	0·147	0·49	5
1898	Panhard and Levassor Van	8	750	—	14·2	1000	2250	3250	406	2050	0·66	0·109	0·355	*
1898	De Dietrich Brake	9	700	—	11·5	1000	2050	3050	339	2020	0·66	0·136	0·42	*
1898	Roser-Mazurier Omnibus	9·5	550	14	9·5	950	2700	3650	400	1930	0·53	0·078	0·296	*
	Electric.											*Watt-hours.*		
1898	Electromobile Van	3·5	—	—	10	750	2070	2850	814	1800	0·63	149	560	—
1898	Kriéger Van	8	—	—	10·2	500	1530	2030	253	1015	0·50	111	451	—
	Steam.											*Coke.* kg.	kg.	
1898	De Dion-Bouton Lurry	30	600	—	11·1	3300	5540	3840	291	5340	0·6	0·423	1·122	4·5
1897	Scotte Train	16	400	—	6·5 to 7	4200	7550	11260	716	5730	0·48	0·53	1·43	3·5
												Petrol Spirit. l.	l.	
1897	De Dietrich Lurry	6·5	660	—	8 to 9	1200	1300	2500	377	1800	0·72	0·115	0·235	3·5
1898	,,	9	700	—	10·8	1500	1870	3370	374	2495	0·74	0·164	0·370	3·5

* Insignificant.

· RACE: PARIS—DIEPPE (ABOUT 170 KM.), 24 JULY, 1897.

Constructor of Vehicle.	Persons Carried.	Type of Motor.	Horse-Power.	Time.		Average Speed in km. per hour (approx.).
				H.	M.	
L. Bollée	1	L. Bollée Petrol	3	4	14	40·4
De Dion-Bouton	4	De Dion-Bouton Steam	6	4	19	39·6
Panhard and Levassor	2	Daimler Petrol	6	4	36	37·2
,,	2	,,	6	4	38	36·8
L. Bollée	1	L. Bollée Petrol	3	4	42	36·4
De Dion-Bouton (Tricycle)	1	De Dion-Bouton Petrol	1½	4	45	35·7
,,	1	,,	1½	4	45	35·7
,,	1	,,	1½	5	5	32·8
A. Bollée	2	A. Bollée	—	5	17	32·3
Panhard and Levassor	2	Daimler Petrol	6	5	19	31·9
Peugeot	2	Peugeot	6	5	28	31·4
Delahaye	6	Delahaye	6	5	41	30
L. Bollée	1	L. Bollée	3	5	44	29·8
Mors	2	Mors	5	5	46	29·6
Delahaye	6	Delahaye	6	5	58	28·6
Peugeot	6	Peugeot	6	6	27	26·5

RACE: PARIS—AMSTERDAM AND BACK (ABOUT 1520 KM.), 7 JULY, 1898.

Constructor of Vehicle.	Persons Carried.	Type of Motor.	Horse Power.	Time.		Average Speed in km. per hour (approx.).
				H.	M.	
Panhard and Levassor	2	Daimler Petrol	8	33	4	44·7
,,	2	,,	8	33	25	42·9
A. Bollée	2	A. Bollée	8	34	8	42
Panhard and Levassor	2	Daimler Petrol	8	34	58	41·1
A. Bollée	2	A. Bollée	8	35	19	40·6
Panhard and Levassor	2	Daimler Petrol	8	35	45	40
Peugeot	2	Peugeot	8	36	20	39·4
,,	2	,,	8	38	26	37·3
Mors	2	Mors	6	38	41	37·1
Peugeot	2	Peugeot	6	39	30	36·3
Mors	2	Mors	6	43	58	32·8
G. Richard	2	G. Richard	4	57	27	25
Motor Cycles.						
Phœbus	1	De Dion-Bouton	1¾	39	36	36·3
De Dion-Bouton	1	,,	1¾	41	20	34·7
Decauville	1	Decauville	2¼	50	14	28·6
De Dion-Bouton	1	De Dion-Bouton	1¾	52	42	27·2
L. Bollée	1	L. Bollée	4	54	3	26·7
De Dion-Bouton	1	De Dion-Bouton	1¾	54	19	26·5
,,	1	,,	1¾	58	51	24·5

TABLES GIVING RESULTS OF AUT

HACKNEY VEHICLE TRIALS: PAR

	Vehicle.	Persons Carried (including Driver).	Horse-Power of Motor.	Type of Fulmen Storage Battery.	Weight of Storage Battery.	Weight of Useful Load (not including Driver.)	
					kg.	kg.	k
1898	Kriéger Coupé	5	3·4	44B/17	457	400	17
1899	,,	3	—	44B/17	484	280	16
1898	Jeantaud Cab	3	3·1	44B/15	404	140	14
1899	,,	3	—	44B/15	449	140	16
1898	Jenatzy Coupé	3	4	44B/21	565	140	18
1899	,,	3	—	44B/17	484	140	19
	Peugeot Coupé	4	6	—	—	210	12

HEAVY VEHICLE TRIALS: LIVERPO

Number of Vehicle.	Constructors.	Total Moving Weight in tons.	Tare in tons.	Useful Load in tons.	Weight of Fuel and Water in tons.	Total Miles Run.
1	Liquid Fuel Engineering Co. (Lifu).	5·340	2·388	2·2	·834	143·5
3	Steam Carriage and Wagon Co. (Thornycroft).	9·551	3·85	4·73	·832	107·4
	,,	6·157	2·825	2·53	·7	143
5	Lancashire Steam Motor Co. (Leyland).	7·426	2·863	4·06	·37	95·9

* In 1898 kerosene was 4d. per

RACE: NICE—CASTELLANE AND BAC

Constructor of Vehicle.	Horse-Power of Motor.	Time. H.	Time. M.	Average per For whole course.
Automobiles.				
Peugeot	17	2	53	41·4
Panhard and Levassor	8	3	19	36
Peugeot	10	3	23	35
De Dietrich	9	3	26	34
Motor Cycles.				
De Dion-Bouton	3	2	59	39
,,	1·75	3	28	34

RACE: PARIS—BORDEAUX (565 KM.), 24 MAY, 1899.

Constructor of Vehicle.	Type of Motor.	Horse-Power of Motor.	Persons Carried.	Time. H. M.	Average Speed in km. per hour.
Panhard and Levassor	Daimler	12	2	11 43	48·1
,,	,,	12	2	11 51	47·4
,,	,,	12	2	12 32	45·05
Mors	Mors	15	2	13 18	42·4
De Dion-Bouton (Tricycle)	De Dion	2·25	1	13 23	42·15
,,	,,	2·25	1	13 25	41·9
,,	,,	2·25	1	13 45	41·02
Phœbus	Aster	1·75	1	15 6	37·32
Mors	Mors	13	2	15 20	36·83
Peugeot	Peugeot	10	2	15 23	36·67
Mors	Mors	10	2	15 51	32·5
A. Bollée	A. Bollée	9·5	—	15 52	32·34

TOUR DE FRANCE (2,219 KM.), 16 JULY, 1899.

Constructor of Vehicle.	Horse-Power of Motor.	Time. H. M.	Average Speed in km. per hour.	Constructor of Vehicle.	Horse-Power of Motor.	Time. H. M.	Average Speed in km. per hour.
Panhard & Levassor	16	44 43	51·1	Decauville	4	125 25	17·6
,,	12	49 37	45·7	*Motor Tricycles.*			
,,	12	49 44	45·56	De Dion-Bouton	2¼	50 58	44·5
,,	12	52 34	43·1	,,	2¼	51 32	44
Amédée Bollée	10	53 29	42·4	,,	2¼	53 38	42·2
Panhard & Levassor	12	58 46	32·5	,,	2¼	55 40	40·6
,,	12	75 45	29·5	,,	2¼	56 7	40·3
Mors	12	80 14	27·8	Aster	—	56 30	40
,,	12	166 6	13·2	De Dion-Bouton	2¼	58 49	38·9
Decauville	4	67 16	33·3	,,	2¼	71 30	31·3
,,	4	75 43	29·5	,,	2¼	93 44	23·7

ACCUMULATOR TRIAL BY AUTOMOBILE CLUB OF FRANCE, 1899.

Type of Accumulator.	Plates. +	Plates. –	Weight.	Space Occupied.	Nominal Number of Charges—Discharges.	Actual Number of Charges.	Actual Number of Discharges.	Total Energy Absorbed.	Total Energy Yielded.	Maximum Monthly Yield.	Minimum Monthly Yield.	Average Yield.
			kg.	dm³.				kilowatt-hours.	kilowatt-hours.	Per cent.	Per cent.	Per cent.
Blot-Fulmen	Pl.	F.	109·8	58·7	135	135	132	210·85	143·9	74	30	68
Fulmen	F.	F.	76·5	39	100	100	98	154·7	101·9	76	55	66
Métaux	Pl.	F.	104	47·4	82	82	71	136·05	76·4	73	36·5	56
Pescetto	F.	F.	128	85·5	141	141	128	228·65	130·6	60·5	48	57
Phœnix	F.	F.	102	57	103	103	102	180·9	118·85	70	51	66
Pollak	F.	F.	110·5	76	82	82	76	133·75	79·55	65	43	59·5
Pope	F.	F.	110	87	135	135	135	220·75	155·5	73	62·5	70
Tudor	Pl.	F.	125·7	62·3	141	139	135	226·65	135·85	66	49·5	60

RICHMOND TRIALS, JUNE, 1899.

						Hill-climbing Trials.				Fifty-mile Efficiency Trials.					
Vehicle.	Total Weight including Passengers (about).	Number of Passengers.	Horse-Power of Motor.	Average Horse-Power at Driving Road Wheels.	Mechanical Efficiency of Vehicle.	Stopped in	At a speed per hour of	Gradient— = one in	Ascended Hill at Speed per hour of	Total Time. H. M.	Average Speed per hour.	Total Consumption of Petrol.	Average Consumption of Petrol per mile.	Distance Run at average speed on 1 gall. of Petrol.	Water Consumption.
	Cwt.				Percent	Feet.	Miles.		Miles.		Miles.	Pints	Pints.	Miles.	Pints
Barriere Tricycle	3·5	1	2	1·24	69	86	14·62	13·85	13·92	4 31·4	11·05	6	0·12	67	—
Benz Dog-cart	20	4	5	3·3	69·4	103	15·03	12·9	5·98	4 4	12·29	18	0·36	22·2	21
Benz Ideal Car	9·75	2	3	1·475	53·4	82·5	16·23	13·85	9·77	4 6·5	12·19	10	0·2	40	11
,,	—	—	—	—	—	—	—	—	—	7 23	6·77	28	0·56	14·28	none
Cannstatt-Daimler Wagonette	24	4	5·5	2·58	49·6	—	—	—	—	4 26·6	11·25	20	0·4	20	—
Daimler Car	27	5	5·5	3·35	66·5	—	—	—	—	—	—	20	0·4	20	—
Daimler Crutchley Light Car	10	2	4	1·34	39	95	12·47	12·9	5·46	4 25	11·24	12	0·24	33·3	17
Daimler Phaeton	23·5	4	5·5	3·41	67·9	47	15·43	12·9	5·35	4 4·5	12·29	12	0·24	33·3	12
Daimler Wagonette	26	4	5·5	3·11	61·7	48	14·65	12·9	4·41	4 18	11·62	18	0·36	22·2	8
Delahaye Phaeton	25	4	8	5·1	71	37	15·96	12·9	7·91	3 23	14·77	12	0·24	33·3	9
Ducroiset Wagonette	31·5	6	10	4·9	54·4	—	—	—	—	3 52·5	12·9	34	0 68	11·76	—
Electrical Undertakings' Dog-cart	—	—	—	—	—	90	—	13·85	10·96	—	—	—	—	—	—
Hercules Car	—	—	—	—	—	87	13·03	12·9	6·11	3 53	12·87	34	0 68	11·76	24
Hertu Phaeton	16	2	4	3·05	83·6	—	—	—	—	7 21·1	6·8	25	0 5	16	—
International Phaeton	11·5	2	3	2·16	78·7	38	10·41	12·9	6·99	6 3	8·26	24	0·48	16·7	54
Lanchester Car	16·5	2	8	2·42	33·4	131	21·28	12	5·75	4 10	12	14	0·28	28·6	none
Lynx	—	—	—	—	—	—	—	—	—	5 12	9·6	10	0·2	40	28
Marshall Car	—	—	—	—	—	74·75	6·99	12·9	7·42	8 11	6·11	26	0·52	15·39	24
Mors Car	21·5	4	7·5	3·92	57·7	20·6	10·8	13·8	7·08	4 52	10·25	10	0·2	40	8
Motor Carriage Supply Co.'s Wagonette	—	—	—	—	—	96·75	14·88	12	4	4 27·5	11·21	20	0·4	20	20
Orient Express Car (Bergman)	15·5	2	4	2·06	57	45	13·34	12·9	5·17	5 32	9·03	28	0·56	14 28	45
Panhard and Levassor Car	20·5	2	8	4·65	64·1	94	13·11	12·9	8·75	4 8·5	12·09	18	0·36	22·2	4
Phœnix Car	—	—	—	—	—	68·6	14·09	13·8	4·58	3 28	14·42	20	0·4	20	55
Riker Car	—	—	—	—	—	98	15·47	12·9	5·71	—	—	—	—	—	—
Tourist Car (Liegeoise)	7	2	3·5	0·89	28	200	—	—	4·95	4 46	10·49	13	0·26	30·76	none
Vallée Car	13·5	2	5	2·67	59·6	106	20·82	12·92	7·8	4 21·5	11·53	26	0·52	15·4	16

PARIS—ROUBAIX ALCOHOL TRIALS (NEARLY 279 KM.), 7 AND 8, APRIL, 1901.

Vehicle.	Weight in Travelling Order.	Time. H.	M.	Consumption of mixture containing 50 per cent. alcohol.	Consumption of mixture per ton-kilometre.
Quadricycles.	kg.			l.	l.
De Dion-Bouton	385	6	4	22·45	·318
Werner	—	15	20	10·5	—
De Dion-Bouton	335	16	31	7·25	·076
Voiturettes.					
Darracq	570	8	2	18	·112
Decauville	550	9	56	37·25	·241
Brierre-Cottereau	560	11	33	33·75	·215
G. Richard	510	12	28	19·6	·137
„	505	14	49	28·85	·202
Renault	520	15	30	22·8†	·156
Light Cars.					
Decauville	590	7	39	64·45	·391
„	745	9	15	36·75	·175
Clément	570	9	32	26·5	·166
Brierre	605	10	3	30·2	·178
Darracq	725	11	14	23·3	·114
Gillet-Forest	725	11	39	22·85	·112
Noé Boyer	620	12	4	30†	·172
Bégot and Cail	780	12	8	32·625*	·149
Brierre	615	12	12	42	·243
Soc. des Téléphones	660	12	30	27	·149
Noé Boyer	620	12	48	32	—
Turgan and Foy	655	12	53	32·5†	·177
Cars.					
Panhard and Levassor	1020	7	7	31·75	·111
„	900	7	12	31	—
Cars (Con.).	kg.			l.	l.
Gobron-Brillié	945	7	46	35·7	·135
Peugeot	1080	8	58	45	—
Panhard and Levassor	890	9	5	32·3	·133
Nesseldorf	1065	10	0	48	·16
Vilain Frères	845	10	27	34·6	·146
Bardon	905	11	25	29·85	·117
Delahaye	925	11	36	24	·092
Gillet-Forest	840	12	12	38·5*	·152
Brouhot	905	12	24	34·5	·134
Delahaye	900	12	32	27	·1075
Brouhot	860	12	54	36·4	·151
Heavy Cars.					
Société Nancienne	1325	6	56	33	·089
A. Bollée	1515	7	48	48·7	—
Delahaye	1240	8	22	34	·0979
Société Nancienne	1240	8	43	41·75	·12
G. Richard	1150	9	31	43·5†	·135
Delahaye	1310	9	55	42	—
Gobron-Brillié	1260	9	48	50·5	·143
Panhard and Levassor	1550	10	18	39·45	—
M. Bollée	1535	11	4	42·5	·0988
Brouhot	1250	11	36	46	·131
Goods Vehicles.					
Bardon	1445	15	35	49†	·121
G. Richard	1735	16	13	70	·144

* Used pure alcohol. † Used mixture containing 75 per cent. alcohol.

AUTOMOBILE CLUB TRIALS.

Vehicle.	Number of Passengers.	Horse Power of Motor.	Weight of Car in lbs.	HILL-CLIMBING. Average Speed in Miles per hour.				
				Taddington.	Shap Fell, No. 1.	Shap Fell, No. 2.	Dunmail Rise.	Birkhill.
Ariel Quadricycle	2	3·125	448	15·13	20·5	6·12	11·41	13·3
Ariel Tricycle	1	2·25	—	18·91	12·5	—	5·13	6·8
Ariel Tricycle with Whippet Attacht.	2	2·25	336	14·4	20·5	6·64	8·22	12·6
Benz Ideal	2	3	1204	5·39	—	—	5·01	6
"	2	3	1176	7·18	11·5	4·8	6·64	6·6
"	2	3	1120	6·7	—	—	4·66	—
Brown Whitney Steam Car	3	—	—	4·56	—	—	7·67	8·9
Century Tandem	2	2·25	—	—	—	—	2·1	10·9
Daimler	2	6	2128	6·3	13·5	6·37	7·9	6·8
"	2	6	2352	6·55	13·5	4·42	6·64	6·6
"	2	6	—	—	—	—	4·66	6·6
"	2	6	—	6·43	—	—	70·8	—
"	2	6	—	—	11	4·42	6·22	4·8
"	3	6	2464	5·8	—	—	6·84	4·1
"	2	6	2016	8·39	13	4·82	8·92	7
"	3	6	2184	8·17	11·5	5·68	7·9	8·2
"	3	12	—	11·19	—	—	5·26	10·4
"	4	12	2828	14·4	—	7·24	10·27	10·9
Daimler Parisian	3	6	2156	9·15	16	—	8·92	8
De Dion-Bouton	2	3	—	—	13·5	7·24	9·79	10·9
"	2	3	784	10·08	14·5	7·58	—	8·2
Decauville	2	3·5	700	6·7	—	—	5·13	—
"	2	3·5	672	6·3	—	—	6·84	8·6
Empress Tricycle	1	2·75	—	—	20	15·94	17·06	—
Enfield Quadricycle	2	2·25	—	9·15	—	—	9·33	12
Gladiator	2	3·25	616	8·17	—	—	7·67	7·5
International Victoria	2	3	—	5·29	—	—	5·55	—
"	2	3	—	6·17	—	—	6·04	4·1
Lanchester	2	8	—	8·62	11·5	4·98	6·84	7·7
Locomobile Steam	2	2	756	9·76	6	6·64	9·79	10·9
Marshall	2	5	1428	—	11·5	4·42	—	—
"	2	5	1372	4·94	10	4·54	6·04	6·3
Mors	2	4	1232	8·39	—	—	7·67	7·5
M. C. C. Triumph	2	3·5	728	9·45	—	—	9·33	9·6
"	2	3·5	—	7·56	—	—	7·33	—
M. M. Co.'s Iveagh Phaeton	4	6	2324	5·49	10·5	4·42	5·13	6·3
M. M. Co.'s Phaeton	3	6	2436	5·29	10·5	5·14	5·86	6·5
"	2	6·25	—	6·3	—	—	—	—
New Orleans	2	3	672	6·3	—	4·42	6·22	7·7
"	2	3	—	6·05	—	—	4·74	—
Napier	3	8	2492	13·74	19	—	13·69	11·5
Panhard	3	6	2128	5·69	10·5	4·8	6·22	5·7
"	3	6	1904	8·17	13	5·68	7·9	8·6
"	4	8	—	10·08	12	5·48	—	—
"	4	12	2378	17·77	27·5	17·71	20·54	16
Peugeot	2	8	1904	9·45	—	—	9·79	10·9
"	2	7	—	7·74	15·5	7·97	9·79	10
Richard	4	7	1792	—	—	—	7·67	7·5
"	4	7	1792	6.43	—	—	5·86	5
Roots & Venables	2	2·87	—	5·8	—	—	—	—
Simm's Motor Wheel	1	2·75	—	9·45	—	—	—	—
Star	2	3·5	—	9·15	—	—	—	8
Wolseley	2	3	1456	10·08	13	6·37	7·9	8·6

HEAVY VEHICLE HILL-CLIMBING TESTS:

Number of Vehicle	Light or Laden.	Total Moving Weight. (T)	Useful Load.	Lowest Gear Ratio Used.	Weight (D) upon Driving-Axle, on level.	D/T
		Tons.	Tons.		Tons.	
A 1	Light	2·10	—	—	1·15	·55
	Laden	3·63	1·53	49·7	—	
A 2	Light	2·12	—	—	1·18	·56
	Laden	3·65	1·53	49·7	—	
B 1	Light	3·77	—	—	2·25	·6
	Laden	8·41	4·76	19·6	—	
C 1	Light	7·65	—	—	5·38	·7
	Laden	14·02	6·77	21·7	—	
D 1	Light	4·63	—	—	2·9	·63
	Laden	8·75	3·75	17·7	—	
D 2	Light	4·60	—	—	2·95	·64
	Laden	9·46	4·91	17·2	—	
D 3	Light	4·75	—	—	3·19	·67
	Laden	9·25	4·75	32	—	
D 4	Light	4· 7	—	—	3·02	·64
	Laden	9·78	4·86	20	—	
D 5	Light	4·68	—	—	2·47	·53
	Laden	10·4	5·51	13	—	

Names of Constructors are given on p. 774.

HEAVY VEHICLE TRIALS: LIVERPOOL, 31 JULY–2 AUGUST, 1899.

Number of Vehicle.	Constructors.	Total Moving Weight in tons.	Tare in tons.	Useful Load in tons.	Weight of Fuel and Water in tons.	Total Miles Run.	Average Speed in Miles per hour.	Consumption per ton-mile of load.			Cost per ton-mile of load.	
								Petroleum in gallons.	Coal in pounds.	Water in gallons.	Motive power.	Attendants.
1	Steam Carriage and Wagon Co. (Thornycroft).	7·465	2·996	3·73	·561	—	—	—	2·38	1·88	·27	·44
2	,,	11·602	3·904	6·65	·812	—	—	—	1·87	1·33	·22	·36
3	T. Coulthard & Co.	4·998	2·238	2·32	·259	—	—	—	—	—	—	—
5	Lancashire Steam Motor Co. (Leyland).	7·753	2·85	4·44	·276	—	—	·121	—	·91	*·62	·38
6	Clarkson and Capel Syndicate	6·765	2·996	3·35	·335	—	—	·216	—	·64	*1·09	·52
9	Bayleys	7·282	2·966	3·67	·447	—	—	—	*Coke.* 1·84	1·27	·13	·65

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* In 1898 kerosene was 4d. per gallon, but in 1899 it was 5d. per gallon.

TABLES GIVING RESULTS OF AUT

LIVERPOOL, 3-7 JUNE, 1901.

Speed of Ascent in miles per hour.				Spe
1 in 18. Macadam (106 yards from rest).	1 in 9½. Sets (50 yards).	1 in 13½. Macadam (90 yards).	1 in 11. Cobbles (87 yards).	1 i Col (87 y from
4·31	3·47	3·8	3·26	4
2·96	2·16	3·94	3·99	4
4·84	4·05	4·2	3·55	6
3·6	2·54	2·67	* 1·92	4·
3·14	2·64	4·01	3·17	3·
3·01	2·55	2·95	2·99	† 3·
3·52	3·99	4·92	2·81	2·
† 3·13	2·56	3·22	2·56	4·
3·28	3·47	4·25	3·9	3·
2·97	2·37	3·46	3·13	3·
3·62	3·78	3·6	* ·57	2·
2·82	2·73	3·54	3·14	3·
3·89	3·17	5·35	3·68	3·
2·91	2·7	3·38	2·71	3·
3·29	3·96	4·12	3·4	3·
2·29	2·36	3·37	3·25	4·
2·55	3·36	4·31	* ·61	4·
1·72	1·79	2·74	* 1·67	3·

* Wheels skidded and slipped. † Lost time in starting. Names

HEAVY VEHICLE TRIALS: LIVER

Number of Vehicle.	Constructors.	Useful Load.	Total ton-miles run.	Total ton-miles of load run.	Average Speed in miles
		Tons.			
A 1	G. F. Milnes & Co.	1·848	663·2	309·2	7
A 2	"	1·888	671·5	316·2	7
B 1	Lancashire Steam Motor Co. (Leyland).	4·813	1,443·6	805·2	6
C 1	Thornycroft Steam Wagon Co.	6·331	2,340·2	1056	6
D 1		4·423	1,529·9	736·9	6
D 2	T. Coulthard & Co.	4·481	1,370·3	666·3	5
D 3	Mann Patent Steam Cart and Wagon Co.	3·612	1,410·6	601·8	5
D 4		4·469	1,558·7	744·5	7

a, Petrol Spirit; *b*, Coke at 15s. per ton; *c*, W

RACE: PARIS—BERLIN (1198·6 KM.), 27-29 JUNE, 1901.

Driver.	Constructor of Vehicle.	Horse Power of Motor.	Time.*		Driver.	Constructor of Vehicles.	Horse Power of Motor.	Time.*	
			H.	M.				H.	M.
Cars over 650 kg.					*Light cars, etc. (Con.).*				
Fournier	Mors	28	16	5	Berteaux	Panhard and Levassor	12	22	35
Girardot	Panhard and Levassor	28	17	7	Sinchalle	Darracq	14	22	46
De Knyff	,,	28	17	11	Edmond	,,	20	23	32
Brasier	Mors	28	17	42	Kraentler	Peugeot	8	25	6
H. Farman	Panhard and Levassor	28	18	21	Rolland	Gobron	8	25	12
Charron	,,	28	18	51	Gondoin	Panhard and Levassor	12	25	46
Axt	,,	24	18	58	Mercier	Gladiator	18	25	49
C. Jarrot	,,	28	19	34	Dernier	Gobron	8	27	46
P. Chanchard	,,	28	19	36	Haban	Nesseldorf	10	31	7
Hourgière	Mors	28	19	38	Collins	Sirène	24	33	38
Heath	Panhard and Levassor	28	19	43	Rigolly	Gobron-Brillié	12	35	58
Voigt	,,	28	20	39	Peschard	Pieper	16	37	59
Laeis	,,	28	21	28	Turgan	Turgan and Foy	8	38	49
Werner	Mercédès	35	22	1	*Voiturettes, 250 to 400 kg.*				
Van der Heyden	Panhard and Levassor	24	22	7	L. Renault	Renault	7	19	31
Clément	,,	28	22	21	Grüs	,,	7	22	58
Lemaitre	Mercédès	35	23	20	Morin	Corre	6	29	7
Rolls	Mors	28	24	1	Merville	Renault	6	34	31
Gast	Panhard and Levassor	20	26	1	Lamy	,,	6	35	40
Brillié	Soc. Nancéene	10	29	20	Delisle	Darracq	6	37	29
De Crawhez	Voiture Piepe	24	29	33	*Motor cycles under 250 kg.*				
De Turckheim	De Diétrich	11	39	41	Osmont	De Dion-Bouton	7	19	15
Light cars, 400 to 650 kg.					Bardean	,,	7	21	4
Giraud	Panhard and Levassor	12	19	51	Cormier	,,	7	22	23
Teste	,,	12	22	34	Bardin	,,	7	22	38

* After deduction of 8 hours allowed for neutralised portions of route in towns, etc.

CONSUMPTION TRIALS. SURESNES—CORBEIL AND BACK (100 KM), FEBRUARY, 1902.

	Car.	H.P.	Density of Petrol at 9° C.	Weight fully loaded. KG.	Consumption in l. per 100 kg.	Consumption in l. per ton kg.	Time. H. M. S.
A	Peugeot	5½	690	550	4·89	·0889	5 9 8
	,,	5½	690	550	4·9	·08909	4 18 52
	G. Richard	3½	712	510	5·58	·109	5 25 14
B	Darracq	6½	716	750	4·85	·0646	5 28 20
	G. Richard	5½	*	600	4·985	·0830	5 17 2
	Korn	6	690	733	5·5	·0750	4 34 10
	De Dion-Bouton	8	690	865	6·33	·0731	4 56 50
	Gladiator	6	714	760	6·998	·0920	5 24 45
	Peugeot	8	700	1,060	8·890	·0838	5 58 0
C	Chenard-Walcker	12	714	1,070	5·5	·0514	4 27 50
	Bardon	5	705	918	6·47	·0704	5 57 0
	Ader	12	700	1,340	—	—	—
D	G. Richard	8	680	1,240	10·	·0806	4 26 10
	Delahaye	7½	690	1,240	10·650	·08580	3 34 30
	,,	12	690	2,060	15·130	·0734	4 16 18

	Car.	H.P.	Petrol density at 9° C.	Weight in kilogs. Loaded.	Weight in kilogs. Useful.	Fuel in litres. Total.	Fuel in litres. Per useful ton kilom.	Per ton kilom. gross.	Time per 100 km.
E	Gillet-Forest	10	716	4,833	1,096	13,290	·20209	·1208	5 3 52
	Dietrich	12	608	2,890	1,060	12,900	·2028	·0744	3 51 0

A, Voiturettes, 250 to 400 kg.; B, cars 400 to 650 kg.; C, 650 to 1,000 kg.; and D, more than 1,000 kg.; E, industrial vehicles. * 50 per cent. Alcohol mixture.

100 MILES NON-STOP TRIAL. U.S.A. AUTOMOBILE CLUB, MAY 30, 1902.

Petrol Cars.	H.P.	Petrol consumed per 100 miles. gals.	Steam Cars.	H.P.	Fuel Consumption in gallons per 100 miles. Petrol.	Fuel Consumption in gallons per 100 miles. Water.
Pierce	5½	4	Grout	4½	12¾	113·15
Long Distance	7	4½	Prescott	4½	13¼	85·5
Darracq	9	5	,,	4½	14	79·5
,,	9	4⅛	Lane	10	15¾	93·25
Packard	12	6½	Locomobile	3½	13½	114·75
Mors	12	7	,,	3½	10	89·25
Georges-Richard	12	8	White	6	6½	6
,,	12	7	,,	6	5¾	6
Autocar	8½	5	,,	6	9	9·75
De Dion-Bouton	4½	6	Overman	4½	10½	84·75
Fournier-Searchmont	8	7	Locomobile	3½	16	103·5
,,	8	8¾				
Haynes-Apperson	9	5				
Knox	6	7				
,,	6	6				
,,	6	7				
Fournier-Searchmont		8½				

100 MILES NON-STOP RUN, LONG ISLAND, U.S.A., APRIL 26, 1902.

No.	Maker.	Net Time. H.	M.	S.	No.	Maker.	Net Time. H.	M.	S.
59	Automotor Co.				38	Elmoro Manufacturing Co.	6	51	30
	Keleconn Motor	6	20	15	47	Autocar Co.	6	52	30
9	Haynes-Apperson	6	22	30	45	Haynes-Apperson	6	56	5
71	Long Distance Co.	6	24	30	43	Ward Leonard Co.	6	58	15
77	Long Distance Co.	6	23	30	72	Olds Motor Works	6	58	15
52	Locomobile Co.	6	26	30	35	Peerless Manufacturing Co.	7	5	0
68	Wheel Within Wheel Co.	6	32	0	27	Torkensen Gear	7	5	45
5	International Co.	6	34	15	53	Locomobile Co.	7	6	45
57	Winton Co.	6	35	40	21	Auto. Co. of America	7	7	20
29	Ohio Automobile Co.	6	37	0	1	Prescot Co.	7	4	30
56	Winton Co.	6	38	15	33	Century Co.	7	6	30
11	Peerless Manufacturing Co.	6	39	0	15	Lane Motor Co.	7	7	30
60	Peugeot & Co.	6	39	40	8	George N. Pierce Co.	7	7	45
25	White Co.	6	39	55	6	International Co.	7	9	45
41	Ward Leonard Co.	6	40	0	18	Auto. Co. of America	7	11	0
26	White Co.	6	40	50	46	Haynes-Apperson	7	11	0
24	White Co.	6	41	15	28	Peerless Manufacturing Co.	7	15	30
13	Panhard-Levassor	6	43	30	2	Prescott Co.	7	21	15
23	Panhard-Levassor	6	46	10	70	Long Distance Co.	7	26	30
30	Ohio Auto. Co.	6	50	30	42	Ward Leonard Co.	7	26	45
	(*Not including* 12 *cars disqualified for exceeding speed limit.*)				63	Haynes-Apperson	7	57	30

ROSLYN HILL CLIMB, U.S.A. (2,800 ft.), APRIL 26, 1902.

No. of Car.	Make of Car.	H.P.	Time on Hill (maximum grade 8p.c.) M.	S.	No. of Car.	Make of Car.	H.P.	Time on Hill. M.	S.
	Class A.					*Class D.*			
53	Locomobile	3½	1	42		Winton	15	1	42
1	Prescot	4½	1	59	56	Peugeot	11	1	46
24	White	6	2	6	60	Packard	12	2	3
54	Grout (V.H.C.)	4	2	6	33	,,	12	2	6
33	Century	8	2	7	29	Haynes-Apperson	9	2	33
26	White	6	8	2	45	Winton	8	2	59
6	Toledo	7½	2	10	57	Auto. Co. of America	9	3	5
25	White	6	2	20	79	(V.H.C.)			
15	Lane	9	2	34		U.S. Long Distance	7	3	38
2	Prescot (H.C.)	4½	2	40	70	Elmore	5	3	57
5	Toledo	7½	11	46	38	Peerless	16	4	4
					11	Haynes-Apperson	9	4	19
					63	Peerless	16	4	32
	Class B.				35	Haynes-Apperson	6	4	45
41	Ward Leonard	5	3	35	46	Gasmobile (H.C.)	9	6	46
42	,,	5	5	3	21	Panhard	16	7	22
43	,,	5	5	36	13				
	Class C.					*Class E.*			
47	Autocar	8	2	30	74	Rochet-Schneider	12—16	1	19
72	Oldsmobile	4	4	16	23	Panhard	16	2	8
8	Pierce	3½	6	42	18	Gasomobile	7	3	42
27	Torkensen	5	10	42	68	Wheel within Wheel Co.	8	4	14

Class A, Steam Cars; B, Electric Cars; C, D and E, Petrol Cars under 1,000 lb., 1,000 lb. to 2,000 lb., and over 2,000lb. respectively.

CONSUMPTION TRIALS AND HILL

No. of Car.	Make and Seating Capacity.	Weight.						Bore and Stroke.	
		Light.			Loaded.				
		Cwts.	Qrs.	Lbs.	Cwts.	Qrs.	Lbs.	Mm.	In.
1	Baby Peugeot (2)	2	2	7	11	0	0	94 ₰ 94	3·7 ₰ 3·7
4	Wolseley (4)	20	0	7	25	3	21	—	4·5 ₰ 5·
5	Benz (3)	24	2	0	29	0	0	130 ₰ 130	5·1 ₰ 5·1
6	Benz (3)	14	0	21	18	1	4	100 ₰ 125	3·9 ₰ 4.92
7	Peugeot (5)	14	3	7	21	3	7	—	—
8	Gladiator (4)	13	3	14	19	0	14	—	—
10	†Gillet-Forest Delivery Van (2)	17	1	0	27	2	0	—	—
11	Century Tandem (2)	6	3	7	10	0	7	—	4·75 ₰ 5·5
12	De Dion-Bouton (2)	8	3	0	13	1	3	—	3·3 ₰ 3·5
13	Rochet (2)	6	1	21	8	3	14	80 ₰ 90	3.14 ₰ 3.54
15	Western Steam Car (2)	11	0	0	13	1	14	—	2.5 ₰ 3.5
21	‡Firefly (4)	17	0	0	23	0	0	96 ₰ 130	3.77 ₰ 5.11
22	French Gardner Serpollet (4)	20	0	14	26	2	7	—	—
24	New Orleans (3)	12	0	14	16	0	0	100 ₰ 105	3.9 ₰ 4.13
25	,, ,,	17	0	7	22	0	14	100 ₰ 105	3.9 ₰ 4.13
26	Foster Steam Car (4)	12	3	7	18	1	21	—	2.5 ₰ 3.5
27	Mors (2)	26	0	0	29	0	0	—	4.75 ₰ 6.5
29	Georges Richard (2)	12	2	0	15	1	0	100 ₰ 110	3.9 ₰ 4.33
32	Gobron-Brillié (4)	19	2	21	25	0	21	95 ₰ 110	3.74 ₰ 4.33
	Motor Bicycles.								
3	Hewetson's (1)	1	1	0	2	3	0	76 ₰ 76	3 ₰ 3
17	Humber Chain-driven (1)	1	0	0	2	1	0	—	2.75 ₰ 3
18	Ormonde Motor Cycle (1)	—			—			66 ₰ 74	2.5 ₰ 2.9
19	Ormonde Motor Bicycle (1)	1	0	21	2	1	14	66 ₰ 74	2.5 ₰ 2.9
20	Ormonde Cycle (1)	1	0	0	2	1	0	66 ₰ 74	2.5 ₰ 2.9
23	Excelsior Motor Bicycle (1)	1	1	21	2	3	0	—	—
28	Phœnix Motor Bicycle (1)	1	1	0	2	2	0	—	2.75 2.75
30	Minerva Motor Bicycle (1)	1	0	0	2	3	7	70 ₰ 70	2.7 ₰ 2.7

* Speeds above 12 miles per hour not recorded. † Solid tyres, all other

BRAKE TESTS. PHILADELPHIA, U.S.A., JUNE 24, 1902.

Car.	Weight in lbs.	Speed in miles per hour (no limit).	Stopped in ft.	in.	Car.	Weight in lbs.	Speed in miles per hour (no limit).	Stopped in ft.	in.
Locomobile (steam)	1,200	27.5	71	0	Mors	2,200	13	10	1
Columbia (electric)	2,700	17.25	40	6	,,	2,200	17.5	22	
Oldsmobile (steam)	950	21	33	0	,,	2,200	18.5	25	2
Autocar	1,400	19.5	59	8	,,	2,200	21.5	40	
,,	1,400	21.5	62	8	,,	2,200	30	91	3
Winton	2,000	23.5	56	5	Runabout (electric)	1,000	14.5	30	4
Mercedes	2,300	25.5	68	2	Autocar	1,400	24	50	10
Packard	2,000	19.75	42	8	Trotting Team	—	21.5	61	0
Columbia (electric)	2,700	12.	12	7	Four in hand	—	17.25	62	8
Panhard	3,000	27.57	74		Bicycle	—	25	185	0
Mors	2,200	8	7	3					

CLIMBS. DASHWOOD HILL, MAY 10, 1902.

Motor.		Trial, A.		Trial, B.		Average Consumption per ton-mile (in Gallons) A and B trials.	Hill Climb, C.		Average Consumption per ton-mile (in Gallons) on Hill Climb.	Percentage of useful load to total weight (approximate).
H. P.	Cyl.	Speed * M. P. H.	Consumption. Gals.	Speed * M. P. H.	Consumption. Gals.		Speed * M. P. H.	Consumption. Gals.		
5	1	12	·84	10.59	·843	·049	—	·337	·153	31
10	2	12	1·375	12	1·25	·032	10·31	·8	·154	20
16	2	12	2·112	—	—	·047*	—	—	—	15
6	2	12	1·05	—	—	·037*	8·47	·931	·253	22
8	2	12	1·375	12	1·168	·037	10·43	·518	·119	33
12	2	12	1·27	12	1·24	·042	12·	·618	·161	27
7	1	12	1·812	12	1·75	·042	4·35	1·175	·214	37
—	1	12	1·125	12	1·15	·093	10·19	·562	·281	32
4½	1	12	1·375	12	1·58	·072	9·38	·525	·198	35
4½	1	12	—	12	·75	·055†	7·88	·3	·171	28
—	2	12	2·75	12	3	·134	11·10	—	—	17
9	2	12	2·5	—	—	·07*	—	—	—	26
6	4	—	—	—	—	—	—	—	—	
9	2	12	·943	12	1	·039	9·39	·625	·195	23
14	4	—	—	—	—	—	—	—	—	—
—	2	—	—	—	—	—	—	—	—	—
28	4	—	—	—	—	—	—	—	—	—
10	2	12	1·93	12	1·125	·064	10·77	·805	·264	18
12	2	12	2·5	12	·2	·057	8·59	1·3	·257	22
—	1	—	—	—	—	—	—	—	—	—
—	1	—	·368	—	·46	—	12	·08	—	—
—	1	—	—	—	—	—	—	—	—	—
—	1	12	·431	12	·393	—	12	·131	—	—
—	1	12	·27	12	·2	—	9·63	·081	—	—
—	1	12	·118	12	·25	—	12	·118	—	—
—	1	12	·318	11.92	·25	—	11·17	·1	—	—
—	—	—	—	—	—	—	—	—	—	—

cars pneumatic. † Tube and electric ignition, all other cars electric only.

GERMAN CONSUMPTION TRIALS. LEIPZIG—EISENACH (177 KM.), JULY 23 and 24, 1902.

Car.	H.P.	Weight.		Time.		Consumption.	
		Light. KM.	Loaded. KM.	H.	M.	Petrol. KM.	Lubricating Oil. L.
De Dietrich (omnibus)	9	1,920	2,920	11	16	31·25	1·6
Fahrzeugfabrik Eisenach III. (delivery van)	5	385	635	12	21	26·6	1·5
Fahrzeugfabrik Eisenach I. (wagon)	10	1,710	3,200	14	32	93·8	4·75
De Dietrich Wagon	9	2,190	5,190	20	18	62·0	2·8
German Military Wagon (alcohol)	10	2,630	5,642	20	39	1.4 & 171·9*	—
Fahrzeugfabrik Eisenach II. (wagon)	12	2,836	5,836	33	7	118·0	5·6

* Alcohol.

ALCOHOL CONSUMPTION TRIAL: CIRCUIT DU NORD, MAY 15-17, 1902.

No. of Car.		Car.	Weight. Light. KG.	Weight. Loaded. KG.	Total Consumption. L.	Consumption in litres per ton-kilometre.	Total Running Time for Three Days. H.	M.	S.
120		Peugeot Cycle	244	423	44·470	·144	28	5	31
133		Darracq Voiturette	392	775	54·235	·096	35	48	22
102	A	Panhard	600	849	91·940	·148	28	57	49
101		G. Richard	411	636	60·440	·130	36	48	50
121		Hurtu	534	912	80·080	·120	34	58	34
126		De Dion	602	910	61·945	·093	38	30	6
135		Gladiator	629	991	95·600	·132	26	38	35
136		,,	630	951	110·310	·158	31	42	33
137		,,	625	911	80·340	·120	28	24	22
143		Delahaye	579	955	88·340	·126	39	4	49
144		,,	572	1,029	69·330	·092	29	49	1
145		Gillet-Forest	564	863	79·405	·126	37	18	3
101	B	Panhard	943	1,284	124·910	·133	25	48	9
108		Gillet-Forest	794	1,104	125·795	·156	25	1	41
110		,,	654	1,090	106·370	·134	35	43	45
123		Bardon	783	1,098	69·710	·086	43	50	45
124		,,	726	1,100	63·170	·078	38	53	18
127		Chenard-Walcker	766	1,202	57·310	·065	31	14	29
147		Hérald	717	1,050	103·900	·135	26	3	8
140		Soc. Nancienne	915	1,337	94·610	·096	22	56	51
142		Delahaye	912	1,372	101·530	·101	30	34	7
138		Prunel	729	1,071	91·750	·117	36	17	1
131		Dietrich	1,104	1,532	113·910	·101	25	11	11

A, Light cars; B, Heavy cars.

FRENCH CONSUMPTION TRIALS. JULY 27, 1902.

	Car.	H.P.	Weight. K.G.	Time. H.	M.	S.	Consumption of Petrol in litres.
A	Mors	16	800	2	43	0	—
	Panhard*	6	790	4	5	50	9·115
	Luc Court	—	—	2	46	0	11·130
	Mieusset	12	800	2	55	7	13·640
	Pilain	16	800	5	52	42	15·7
	De Dietrich	12	800	3	9	10	20·360
	Richard	16	1,125	3	5	8	40·090
B	De Dion*	8	550	3	49	27	8.103
	Schaudel	9	550	3	42	12	9.325
	G. Richard	10	640	3	55	9	10.575
	Liberia	6½	650				9.435
C	Peugeot*	5	350	4	28	22	7·206
	Clément	5	300	4	42	29	9·535
	Teste-Moret	3	300	5	59	0	10·202
D	Gladiator	1¼	35	4	1	31	—
	Maurice	1¾	63	4	37	40	4·003
	Clément	1¼	35	5	54	0	—

A, Heavy cars; B, Light cars; C, Voiturettes; D, Motor cycle.

RACE: PARIS—VIENNA (991 KM.), JUNE 27—29, 1902.

Order of placing.	Entry No.	Driver.	Make of Car.	Time.									Penalisations.			Total time, 991 km.		
				1st Stage, Paris-Belfort, 376 km.			2nd Stage, Bregenz-Salzburg, 318 km.			3rd Stage, Salzburg-Vienna, 297 km.								
				H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.
		A																
1	7	H. Farman	70-h.p. Panhard	4	30	1⅗	5	46	31⅗	5	38	57	0	5	0	16	0	30⅕
2	26	Zborowski	40-h.p. Mercedes	5	3	50⅖	5	50	34⅕	4	43	5	0	36	0	16	13	29⅗
3	6	M. Farman	70-h.p. Panhard	4	40	45	6	52	54⅖	4	43	50	0	2	0	16	19	29⅖
4	17	Teste	70-h.p. „	4	47	48⅖	6	16	42⅖	5	41	58	0	27	0	17	13	28⅘
5	9	Pinson	70-h.p. „	4	54	55⅕	6	7	22⅕	6	56	24	0	2	0	18	0	41⅖
6	202	P. de Crawhez	40-h.p. „	5	6	14	6	41	15⅖	5	31	51	0	46	0	18	5	20⅖
7	140	Chauchard	40-h.p. „	6	28	9	6	30	45⅖	4	54	51	0	23	0	18	16	45⅖
8	45	*Edge	60-p.p. Napier	6	6	18⅗	7	30	48⅕	5	36	15	0	3	0	19	16	21⅘
9	3	De Caters	60-h.p. Mors	5	52	38	8	58	25⅕	4	54	55	0	9	0	19	54	58⅕
10	217	G. de Crawhez	40-h.p. Panhard	6	9	20⅕	7	33	16⅕	6	12	0	0	12	0	20	6	36⅖
11	8	Jarrott	70-h.p. „	4	30	9⅗	9	39	7⅖	6	14	55	0	20	0	20	44	12.
12	10	Leys	70-h.p. „	6	15	36⅗	6	22	54	7	30	22	0	43	0	20	51	52⅗
13	90	Augières	40-h.p. Mors	7	14	14⅕	7	21	2⅗	5	4	34	1	38	0	21	17	50⅘
14	197	Sabis-Bey	40-h.p. Panhard	6	31	27⅘	8	24	3⅖	6	3	51	1	10	30	22	9	52⅕
15	81	Chanliaud	12-h.p. Gard.-Serp.	6	11	14⅘	8	52	2⅖	7	0	51	0	23	30	22	27	38⅕
16	192	Gavaris	24-h.p. Panhard	7	43	7⅘	9	0	35⅖	6	47	48	0	48	0	24	19	31⅕
17	82	Le Blon	12-h.p. Gard.-Serp.	6	59	14⅖	8	53	41⅗	8	12	24	0	15	0	24	20	20
18	55	Merville	16-h.p. De Dietrich	8	4	57⅗	9	24	38	6	20	20	0	30	58	24	20	53⅗
19	184	Rouquette	16-h.p. Peugeot	8	38	26⅖	7	27	47	7	57	38	0	50	52	24	54	43⅖
20	80	Rutishauser	12-h.p. Gard.-Serp.	11	37	55⅗	9	5	39	6	14	17	0	47	0	27	44	51⅗
21	205	Olliver	12-h.p. „	8	45	44⅘	11	3	37⅕	8	26	56	0	31	30	28	47	48
22	158	Cornilleau	18-h.p. Decauville	13	49	25⅗	11	53	37	8	45	.15	0	33	15	35	1	32⅗
22	83	Cottard	12-h.p. Gard.-Serp.	9	9	31⅗	12	23	0	21	45	0	4	35	0	47	52	31⅖
		B																
1	147	M. Renault	16-h.p. Renault	5	33	5⅘	5	37	35⅗	4	7	7	0	29	56	15	47	43⅘
2	38	Edmond	24-h.p. Darracq	4	48	58	5	58	29⅕	5	6	49	0	16	0	16	10	16⅕
3	35	Barras	24-h.p. „	5	5	38⅘	7	15	47⅖	4	39	36	0	4	0	17	4	52
4	39	Hémery	24-h.p. „	5	12	25⅘	7	16	25	4	41	48	0	13	0	17	23	38⅘
5	30	Marcellin	24-h.p. „	5	31	57	6	10	30⅕	5	46	30	0	9	33	17	38	36⅕
6	50	Tart	20-h.p. Clément	6	2	7⅗	7	10	2	5	2	0	0	7	36	18	26	45⅗
7	95	Berteaux	24-h.p. Panhard	5	33	49⅘	6	22	6⅕	5	1	5	1	31	0	18	28	0⅗
8	40	Collin	24-h.p. Darracq	5	40	13⅕	7	42	58⅘	5	30	6	0	14	30	19	16	47⅗
9	103	Barbaroux	20-h.p. Clément	6	28	35⅗	7	7	26⅘	5	22	14	0	52	45	19	51	1
10	23	Déchamps	20-h.p. Déchamps	7	15	11	7	26	4⅗	5	0	10	0	35	0	20	16	25⅗
11	63	Dernler	18-h.p. Gobron Nagant	6	14	44⅗	8	12	1⅗	6	3	41	0	15	30	20	45	57⅕

RACE : CIRCUIT DES ARDENNES (512·4 KM.), JULY 31, 1902.

Official No.	Driver.	Car.	Total time for 512·4 km. H. M. S.
	Large Cars (up to 1,000 kg.).		
32	Jarrott	Panhard	5 53 39⅗
27	Gabriel	Mors	6 2 45⅕
29	Vanderbilt	,,	6 22 11⅗
61	Comte Zborowski	Mercedes	6 46 40⅕
18	Girardot	C.G.V.	6 55 55⅖
31	Heath	Panhard	6 57 0⅗
28	Rugières	Mors	7 43 56⅕
21	Loraine-Barrow	De Dietrich	8 9 3⅖
4	F. Coppée	Germain	8 14 3
22	Stead	De Dietrich	18 18 26
30	Hautrast	Pieper	9 11 29⅕
5	Wattecamps	,,	9 15 24⅕
	Light Cars (400 to 650 kg.).		
35	Rigolly	* Gobron-Brillié	6 52 16⅘
2	Guders	Panhard	7 1 46⅗
65	Edmond	Darracq	7 4 30
75	Durand	Mors	7 24 53⅖
72	Berteaux	Panhard	7 26 47⅘
54	De La Touloubre	Decauville	7 36 38⅖
58	Uhlmann	,,	7 37 53⅖
38	Tart	Clément	7 50 15
39	Barbaroux	,,	7 59 6⅗
36	Perrin	Delahaye	8 0 14
67	Collins	Darracq	8 3 9⅘
37	De Laugril	Delahaye	8 4 37
45	Dernier	Gobron-Nagant	8 58 2
	Light Cars (400 to 65 kg. contd.)		
59	Page	Decauville	9 26 29
57	Marot	Decauville	10 23 40
46	Courard	Gobron-Nagant	10 32 15
	Voiturettes.		
48	Corre	Corre	9 34 39⅕
40	Voulatum	Clément	10 23 40⅖
62	Lura	Prunet	12 12 37⅕
15	Kuhling	Vivims	12 21 14⅕
63	Tellier	Passy	12 25 26⅕
	Tourist Cars.		
20	Gregoire	Germain	10 12 58⅕
3	Van der Speack	,,	10 32 20⅖
	Motocycles (total distance 170·8 km.).		
—	Osmont	De Dion-Bouton (8 h.p.).	2 53 44⅕
—	De Goostens	Korn (9 h.p.)	3 9 11
	Motor Bicycles (total distance 170·8 km.).		
—	Derny	Clement	3 9 47⅘
—	Elskamp	Minerva	3 26 39⅕
—	Arnott	Werner	3 36 5⅗
—	Philtiens	Philtiens	3 42 30⅗
—	Masson	Clemont	3 43 54⅗

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* Alcohol

RELIABILITY TRIALS, HILL CLIMBS. SEPTEMBER, 1902.

Official No.	Car, and Seating Capacity.*	River Hill. Time. M. S.	River Hill. Marks.	River Hill. Speed in Miles per hour.	Westerham Hill (Betson's). Time. M. S.	Westerham Hill (Betson's). Marks.	Westerham Hill (Betson's). Speed in Miles per Hour.	Average h.p. on Hill.	Gross Fuel-Consumption.
1	Chain-driven Humber Bicycle (1) ...	1 59 (1)	418	21·1	1 55 (1)	—	—	1 32	5·3
2	Chain-driven Humber Bicycle (1) ...	7 21⅗ (1)	—	—	16 43 (1)	—	—	—	—
4	Century Tandem (2)	4 16⅕ (2)	137	9·8	4 53⅖ —	—	—	2·31	11·5
5	Baby Peugeot (Friswell, Ltd.) (2) ..	4 27⅗ (2)	125	9·3	4 34⅕ (2)	130	7·3	2·48	13·0
6	Werner Cyclette (1)	—	—	—	—	—	—	—	—
7	Ormonde Bicycle (1)	6 28⅕ (1)	—	—	6 23⅗ (1)	—	—	—	—
8	Oldsmobile (F. W. Peckham) (2)	—	—	—	—	—	—	—	—
9	Locomobile, Steam (2)	2 46⅕ (2)	57	15·1	2 44⅕ (2)	61	12·2	5·37	45·5
10	Locomobile, Steam (2)	3 12 (2)	47	13·0	3 44⅘ (2,	42	8·9	4·23	47·5
11	Swift (2)	8 57⅗ (2)	—	—	¶	—	—	—	—
12	Parr Light Car (4)	—	—	—	—	—	—	—	—
19	Star (4)	7 53 (4)	35	5·3	7 36⅕ (4)	38	4·3	2·85	26·0
20	Locomobile, Steam (2)	3 24⅗ (2)	39	12·2	4 1⅕ (2)	35	8·3	4·22	38·0
21	Locomobile, Steam (2)	3 4⅘ (2)	36	13·5	3 3 (2)	39	10·9	5·29	47·0
22	Renault (Roadway Autocar Co.) (2) ...	5 35⅗ (2)	55	7·4	6 22⅖ —	—	—	2·05	15·2
23	M.M.C. Voiturette (4)	6 14⅘ (4)	52	6·7	5 43⅗ (4)	60	5·8	2·85	20·0
24	De Dion Bouton (3)	4 12⅖ (3)	84	9·9	4 19⅗ (3)	87	7·6	3·31	15·8
26	White Steam (2)	3 41⅗ (2)	53	11 3	6 27⅗ (2)	52	5·1	3·52	27·6
28	Georges Richard (2)	—	—	—	—	—	—	—	—
29	White Steam (2)	4 5⅖ (2)	53	10·2	3 63⅗ (2)	63	9·2	4·52	26·0
30	Decauville (Motor Car Co., Ltd.) (2) ...	5 40 (4)	25	7·3	4 57⅗ (4)	31	6·7	4·17	36·35
31	Georges Richard (4)	5 0⅗ (4)	45	—	13 17⅕ —	—	—	—	—
32	James and Brown (4)	5 42⅗ (4)	40	7·3	5 13⅘ (4)	47	6· 4	4·61	26·5
33	Gladiator (S. F. Edge) (4)	4 31⅕ (4)	48	9·2	7 12⅗ (1)	23	4·6	3·35	23·6
35	Brooke (4)	7 32⅖ (4)	25	5·5	6 15⅗ (4)	32	5·3	3·97	35·25
36	Simms (4)	5 45⅘ (4)	47	7·2	9 20⅘ —	—	—	3·45	19·65
38	Star (4)	—	—	—	—	—	—	—	—
39	Wolseley (4)	5 18 (4)	—	—	40 32 (4)	—	—	—	**
40	Wolseley (4)	5 32⅗ (4)	28	7·5	16 19 —	—	—	3·8	41·71
41	Wolseley (4)	5 5⅗ (4)	49	8·2	4 22 (4)	61	7·6	5·68	27·2
42	Belsize (Marshall and Co.) (4)	6 4⅗ (4)	40	6·8	6 33 (4)	39	5·7	4·1	27·0
44	New Orleans (4)	4 42⅗ (4)	53	8·8	4 46⅕ (3)	51	7·2	3·85	23·5
47	De Dion-Bouton (4)	5 2⅗ (4)	51	8·3	5 6⅗ (2)	46	6·5	3·74	23·5
48	Clement (2)	6 49⅗ (2)	31	6·1	19 30⅗ —	—	—	2·7	23·9
51	Gladiator (S. F. Edge) (4)	3 52⅕ (4)	40	10·8	3 57⅗ (4)	42	8·4	5·53	27·5
52	Ariel (4)	4 48 (4)	40	8·7	5 7 (1)	32	6·5	4·08	25·2
53	New Orleans (4)	—	—	—	—	—	—	—	—
54	Century (F. Milburn) (4)	4 46⅕ (4)	66	8·7	5 23 (3)	59	6·2	4·98	19·0
56	New Orleans (Wm. Exe) (4)	—	—	—	—	—	—	—	—
57	M.M.C. (4)	6 58⅕ (4)	24	6·0	5 45⅗ (4)	31	5·8	7·42	30·0
59	Germain (Motor Traction Co., Ltd.) (4) ...	6 46⅕ (4)	25	6·1	7 23⅕ (4)	24	4·5	3·63	33·0
60	Georges Richard (2)	—	—	—	—	—	—	—	—
62	Gardner-Serpollet Steam (4)	2 29⅗ (4)	38	16·7	3 3 (4)	29	10·9	10·18	50·66
63	Gardner-Serpollet Steam (4)	2 34⅘ (4)	39	16·2	3 44⅗ (4)	29	8·8	8·77	43·0
64	Peugeot (Friswell, Ltd.) (4)	3 0 (4)	56	13·9	4 17 (4)	42	7·8	7·64	26·0
65	Brush (4)	4 52⅕ —	25	8·5	25 1⅖ (2)	5	1·3	3·05	37·0
66	Humber (4)	5 19 (3)	26	7·8	4 46⅗ (4)	30	6·9	5·60	28·6
67	Humber (4)	—	—	—	—	—	—	—	—
69	Wolseley (4)	3 2⅘ (4)	34	13·7	2 40⅖ (4)	41	12·5	12·43	51·0
70	Mors (Roadway Autocar Co.) (4) ...	—	—	—	—	—	—	—	—
71	Wilson and Pilcher (4)	5 0⅗ (4)	26	8·3	13 57 (4)	10	2·3	3·87	33·1
74	Germain (Motor Traction Co., Ltd.) (4) ...	3 23⅕ (4)	36	12·3	3 14⅘ (4)	40	10·2	8·77	33·0
75	Clement (2)	3 21⅕ (4)	29	12·4	2 27⅕ (4)	35	11·3	7·28	32·5
76	Daimler (5)	4 18⅖ (5)	28	9·7	4 18⅗ (5)	30	7·7	7·13	3·28
77	Daimler (4)	—	—	—	—	—	—	—	—
81	M.M.C. (4)	3 54⅗ (4)	20	10·7	13 5⅖ (2)	6	2·5	4·62	44·5
82	Maudslay (4)	4 24 (4)	26	9·5	4 33⅗ (4)	27	7·3	7·34	33·0
83	Pascal (Baron Henri de Rothschild) (4) ...	2 44 (4)	28	15·3	3 9⅘ (4)	25	10·5	11·73	51·5
84	Pascal (Baron Henri de Rothschild) (4) ...	4 48 (4	22	8·7	3 59⅖ (4)	28	8·3	7·18	34·8
86	Daimler (4)	3 12⅖ (4)	28	13·0	2 52⅕ (4)	33	11·6	11·39	32·5
87	Daimler (5)	3 3 —	21	13·7	—	¶	—	11·59	48·0
88	Panhard (4)	2 32⅕ (4)	41	16·5	2 57⅖ (4)	37	11·3	9·41	21·0

* For classes see next page. ¶ Broke down. ** Not received.

AUTOMOBILE CLUB 650 MILES RELIABILITY TRIALS, SEPTEMBER 1—6, 1902.

Official No.	Car, and Seating Capacity.	Motor.			Marks and Results.												Weight.		
		H.P.	No. of Cylinders.	Bore and Stroke of Cylinders. mm. or inches.	Mon., Sept. 1, Folkestone, 139¼ miles.	Tues., Sept. 2, Eastbourne, 120 miles.	Wed., Sept. 3, Worthing, 120 miles.	Thur., Sept. 4, Brighton, 87¾ miles.	Fri., Sept. 5, Tonbridge and Hill Climb and Consumption, 61¾ miles.	Sat., Sept. 6, Bexhill, 121¾ miles.	Daily Marks for the Week.	Marks for Condition at End of Trial. Max. 500.	Marks for Steering Gear. Max. 250.	Marks for Brakes. Max. 250.	Grand Total Marks.	Price of Car.	Laden.	Un-laden.	Fuel Consumption per Cwt. of Car Loaded.
	CLASS A.—*Price £150.*															£	cwt.	cwt.	
1	Chain-driven Humber Bicycle (1) ...	3	1	3 in. × 3 in.	300	295	300	300	300	300	1,795	430	250	250	3,243	60	2·607	1·34	2·607
2	Chain-driven Humber Bicycle (1) ...	2	1	2¾ in. × 3 in.	300	298	292	300	282	300	1,772	325	200	250	2,547	50	—	1·46	—
4	Century Tandem (2)	5	1	84 × 90	294	300	296	300	300	300	1,790	500	250	125	2,872	145	9·607	6·5	1·19
5	Baby Peugeot (Friswell, Ltd.) (2)	5	1	100 × 100	299	300	300	300	300	300	1,799	425	250	250	3,057	150	10·75	6·5	1·23
6	Werner Cyclette (1)	1¾	1	64 × 72	300		—	—	—	—	—	—	—	—	—	—	—	—	—
7	Ormonde Bicycle (1)	1½	1	65½ × 74	300	282	270	300	270	295	1,717	225	250	250	2,412	42	—	1·09	—
	CLASS B.—*Price £150 - £200.*																		
8	Oldsmobile (F. W. Peckham) (2) ...	4	1	4½ in. × 6 in.	¶	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	Locomobile, Steam (2)	5½	2	2½ in. × 3½ in.	273	262	283	277	298	293	1,686	400	250	900	2,753	200	14·25	11·25	3·19
10	Locomobile, Steam (2)	5½	2	2½ in. × 3½ in.	289	293	284	291	281	295	1,736	450	250	150	2,754	200	14·0	11·25	3·31
11	Swift (2)	4½	1	84 × 90	299	282	295	295	†	—	—	—	—	—	—	—	—	—	—
	CLASS C.—*Price £200—£300.*																		
12	Parr Light Car (4)	8	1	4½ in. × 4½ in.	288	¶	—	—	—	—	—	—	—	—	—	—	—	—	—
19	Star (4)	7	2	3¾ in. × 4½ in.	273	297	291	294	300	263	1,718	300	200	200	2,568	300	21·25	15·5	1·22
20	Locomobile, Steam (2)	5½	2	2½ in. × 3½ in.	292	233	295	—	290	272	1,382	350	250	150	2,279	300	15·07	12·25	2·52
21	Locomobile, Steam (2)	5½	2	2½ in. × 3½ in.	296	295	296	298	298	297	1,780	440	250	150	2,784	300	15·5	12·25	3·03
22	Renault (2)	4½	1	3⅝ in. × 4 in.	·267	258	295 †	300	287	217	1,624	485	250	250	2,721	245	11·357	7·25	1·32
23	M.M.C. Voiturette (4)	8	1	100 × 130	266	295 †	295 †	295	300	300	1,751	500	250	250	2,982	255	16·357	10·28	1·22
24	De Dion Bouton (3)	6	1	90 × 110	268	299	282	300	300	286	1,735	440	250	200	2,914	215	13·5	8·5	1·17
26	White Steam (2)	6	2	3½ in × 4 in.	226	296	300	300	300	300	1,722	500	250	125	2,749	300	16·07	13·12	1·71
28	Georges Richard (2)	10	2	100 × 100	§	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29	White Steam (2)	6	2	3½ in. × 4 in.	300	300	300	299	300	300	1,799	500	250	125	2,862	300	16·607	13·03	1·56
	CLASS D.—*Price £300—£400.*																		
30	Decauville (Motor Car Co., Ltd.) (2)	10	2	110 × 110	295 †	295	280	300	300	300	1,770	440	240	250	2,868	410	21·07	16·25	1·72
31	Georges Richard	10	2	100 × 100	297	293	300	300	291	¶	—	—	—	—	—	—	—	—	—
32	James and Browne (4)	9	2	4 in. × 6 in.	300	298	295	300	295	·90	1,770	465	250	200	2,901	400	24·107	16·07	1·10
33	Gladiator (S. F. Edge) (4)	12	2	90 × 110	300	300	300	300	289	300	1,789	500	250	50	2,785	400	20·178	14·0	1·79
35	Brooke (4)	10	3	3½ in. × 4¾ in.	289	300	286	299	300	300	1,772	470	250	250	2,885	395	25·75	20·5	1·38
36	Simms (4)	8	2	95 × 110	299	298	38	300	294	297	1,526	0	250	0	1,922	375	19·75	14·0	0·99
38	Star (4)	10	2	4½ in. × 5½ in.	292	¶	—	—	--	—	—	—	—	—	—	—	—	—	—

39	Wolseley (4)	10	2	4½ in. × 5 in.	300	300	295 †	300	166	290 †	1,651	495	250	250	2,646	380	26·5	—	—
40	Wolseley (4)	7½	2	4 in. × 4 in.	300	299	300	300	289	297	1,785	500	250	200	2,862	325	21·105	15·5	1·97
41	Wolseley (4)	10	2	4½ in. × 5 in.	300	300	295 †	300	300	300	1,795	500	250	200	2,981	380	25·57	20·0	1·06
42	Belsize (Marshall and Co.) (4) ...	12	2	4 in. × 4½ in.	300	300	300	300	300	295	1,795	475	250	200	2,887	385	25·0	18·87	1·18
44	New Orleans (4)	9	2	100 × 110	295	299	300	300	300	300	1,794	485	250	200	2,948	315	18·14	12·56	1·29
47	De Dion Bouton (4)	8	1	100 × 120	270	269	300	300	300	299	1,758	500	250	250	2,982	328	19·75	12·5	1·19
48	Clement (2)	8	2	3$\frac{1}{16}$ in. × 3$\frac{9}{16}$ in.	248	293	293	263	287	294	1,678	425	250	250	2,674	305	18·25	—	1·30
	Class E.—*Price* £400—£500.																		
51	Gladiator (S. F. Edge) (4)	12	4	75 × 110	196	298	300	249	300	300	1,643	495	250	50	2,694	500	21·285	13·25	1·28
52	Ariel (4)	10	2	3$\frac{15}{16}$ in. × 4 in.	279	252	285	273	287	272	1,648	480	250	250	2,814	450	21·39	16·0	1·17
53	New Orleans (4)	14	4	100 × 110	299	300	300	300	¶	—	—	—	—	—	—	—	—	—	—
54	Century (F. Milburn) (4)	12	2	88 × 110	250	298	6	300	298	300	1,452	240	150	0	2,082	420	21·85	18·25	0·76
56	New Orleans (Wm. Exe) (4) ...	14	4	100 × 110	299	¶	—	—	—	—	—	—	—	—	—	—	—	—	—
57	M.M.C. (4)	10	2	100 × 130	292	269	290	300	284	299	1,734	415	240	200	2,747	450	22·75	16·5	1·31
59	Germain (4)	7½	2	95 × 130	297	300	300	300	300	294	1,791	490	250	250	2,912	450	24·75	18·06	1·33
60	Georges Richard (2)	20	4	100 × 100	¶	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Class F.—*Price* £500 - £600.																		
62	Gardner-Serpollet Steam (4) ...	6	4	55 × 92	300	297	233	288	300	295 †	1,713	495	250	150	2,879	600	28·25	22·5	2·23
63	Gardner-Serpollet Steam (4) ...	6	4	55 × 92	291	278 †	298	300	300	294	1,761	500	250	150	2,930	600	28·89	22·56	2 69
64	Peugeot (Friswell, Ltd.) (4)	10	4	94 × 94	299	299	300	295 †	300	300	1,693	475	250	250	3,113	600	26·05	14·21	0·99
65	Brush (4)	10	4	85 × 118	300	222	236	292	284	300	1,634	465	250	200	2,687	550	24·857	19·35	1·08
	Class G.—*Price* £600—£700.																		
66	Humber (4)	12	4	3¾ in. × 4 in.	300	294	300	300	300	300	1,794	470	250	200	2,892	700	27·107	20·0	1·05
67	Humber (4)	12	4	3¾ in. × 4 in.	174	¶	—	—	—	—	—	—	—	—	—	—	—	—	—
69	Wolseley (4)	20	4	4½ in. × 5 in.	300	300	300	300	300	300	1,800	495	250	200	3,030	650	31·00	26·0	1·5
70	Mors	10	4	3$\frac{7}{8}$ in. × 4¾ in.	255	300	274	300	¶	260	—	—	—	—	—	—	—	—	—

TYRE TRIALS: AUTOMOBILE CLUB (3,000 MILES, EXTENDED

Marks Lost

Official No.	Tyres.	Folkestone, 139¾ miles. Sept. 1.	Eastbourne, 120 miles.	Worthing, 120 miles.	Brighton, 87½ miles.	Westerham, 61 miles.	Bexhill, 121¼ miles.	Fareham, 149¾ miles.	Mkt. Harboro', 108¼ miles.	Marlborough, 149 miles.	Havant, 155 miles.	Salisbury, 162½ miles.	Banbury, 151 miles.	Oxford, 155 miles.	Maidstone, 189¼ miles.	Canterbury, 152¼ miles.	Newmarket, 153¼ miles.	Newbury, 159½ miles.	Oxford, 149¾ miles.
T. 1	Dunlop... ...	18a		1a			5a	3a					3a	3a				2a	4a
T. 2	,, ...					1a	39b	6a			6a		3a			1a			
T. 3	,, ...	1b	16a	24b	13a					2a			2b	2a				2a	2b
T. 4	,, ...				1b		22b	29b	33a	11b		45a	31c	—	2a	13b	13a	3a	21c
T. 5	,, ...			c	—	—	—	—	—	—	—	—	—		—	—	—	—	—
T. 6	Maison Talbot	13c	62b								b		d		b	c	44b	75b	45d
T. 7	Collier Twin...			2d	3b	4a					c			25b				3a	
T. 8	Martin ...	d						c			201d		e	—	—	—	—	—	—
T. 9	,, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
T. 10	Goodyear ...		11c	51e			98c	75d	40b	33c		43b	203f	8c	123c	140d	c	—	—
T. 11	,, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
T. 12	E. Midgeley...	16e	6d			1b	2a	2a		2a		2c	4a	2a			1d		2b
	Cars.																		
T. 1 T. 2 T. 3 T. 4 T. 5 T. 6 T. 7 T. 8 T. 10 T. 12	12-h.p. Panhard 11-h.p. Napier... 10-h.p. Panhard 10-h.p. Wolseley 12-h.p. Clement 16-h.p. ,, 11-h.p. Napier... 12-h.p. M. M. C. 10-h.p. Wolseley 16-h.p. Napier...	*a.* Tube burst. *b.* Pumping in garage. *c.* Tyre punctured. *d.* Car troubles; 38 miles to make up. *e.* Tube or tyres changed; faulty valve.	*a.* Pumping in garage and on road; tube removed, and minor difficulties. *b.* Tube and cover changed. *c.* Tube burst, and pumping on road. *d.* Tube burst.	*a.* Pumping in garage. *b.* Pumping in garage; tyre punctured; tube or tubes changed. *c.* Ceased to run. *d.* Nail or stone extracted. *e.* Tyre punctured.	*a.* Pumping in garage and tyre punctured. *b.* Pumping in garage.	*a.* Pumping in garage. *b.* Nail or stone extracted.	*a.* Pumping in garage. *b.* Tube or tubes changed. *c.* Tyre punctured.	*a.* Pumping in garage. *b.* Pumping in garage and tyre punctured. *c.* 24·75 miles to make up; three passengers alighted for 32-yd. patch of stones. *d.* Tyre punctured; four bolts and one nut broken.	*a.* Pumping in garage and tyre punctured. *b.* Tyre burst.	*a.* Pumping in garage. *b.* Pumping in garage; tube or tubes changed. *c.* Tyre burst; nail or stone extracted.	*a.* Pumping in garage. *b.* 140 miles to make up. *c.* 75·25 miles to make up; collision. *d.* Three hours 21 minutes fitting new tyre; most of time one wheel was out of Club's custody.	*a.* Tube or tubes changed. *b.* Tyre burst; near outer cover and tube fitted. *c.* Pumping in garage.	*a.* Pumping in garage. *b.* Repairing cut cover. *c.* Nail or stone extracted; back tyres changed to front. *d.* Car broke down and towed to garage. *e.* Ceased to run. *f.* Two inner tubes changed and patched; car ran 62 miles out, returning same route instead of route laid down.	*a.* Pumping in garage. *b.* Tube or tubes changed. *c.* Pumping in garage; faulty valve.	*a.* Pumping in garage. *b.* Car under examination; 139·5 miles to make up. *c.* Tyre burst; tube changed; nail or stone extracted.	*a.* Nail or stone extracted. *b.* Tube ripped. *c.* Tyres refitted; 152·25 miles to make up. *c.* Tyre repairs.	*a.* Tyre punctured. *b.* Tube or tubes changed; faulty valve. *c.* Ceased to run. *d.* Nail or stone extracted.	*a.* Pumping in garage. *b.* Tube or tubes changed.	*a.* Pumping in garage; nail or stone extracted. *b.* Pumping in garage. *c.* Tube burst; faulty valve. *d.* New nail catcher fitted.

* One mark was deducted for each minute or part of minute occupied in

TO 4,000 MILES), SEPTEMBER 1 TO OCTOBER 15, 1902.

Daily,* Destination and Miles Run.

Norman Cross, 159¾ miles.	Worthing, 158¼ miles.	Dover, 187 miles. Sept. 26.	Winchester, 151¾ miles. Sept. 29.	Eastbourne, 143 miles. Sept. 30.	Chichester, 145 miles. Oct. 1.	Cambridge, 118¼ miles. Oct. 2.	Folkestone, 147½ miles. Oct. 3.	Oct. 4.	Bicester, 126½ miles. Oct. 6.	Dorchester, 117 miles. Oct. 7.	Oct. 8	Oct. 9.	Oct. 10.	Oct. 12.	Oct. 13.	Oct. 14.	Oct. 15.	Total Marks Lost.	Total Miles Run.	Marks Lost per 1,000 Miles (approx.).
			57a			6a			a		a	—	com	plet	ed r	un	—	96a	4,000	24
	a		8b	1a	1a				15a.b	1a	a	a	a		2a	2a	finish'd run.	87	4,000	21·7
	69b				8b	11b					a	—	com	plet	ed r	un.	—	152	4,000	38
	11c	27a	12c		3b	12c	9a			15b	9b	—	com	plet	ed r	un.	—	322	4,000	80·5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	259a	—
		210b	86d	3b					1c	c	15c	18b	33b	24a	60b	9b	finish'd run.	698	4,000	174·5
			4e			3a		a	d	c	d	1c	c	finis	hed	run.	—	48a	4,000	12
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	201	1,371a	146·6
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	825	2,032a	406
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	26d	c	3f	c	c	d	b	b	a	37d	a	a	72d		6c	15c	a	199	3,700a	53·7
	a. 158·5 miles to make up. *b.* Pumping in garage; both tube and tyre burst. *c.* Tyre punctured. *d.* Tyre burst.	*a.* Tyre burst. *b.* Pumping before start; Maidstone puncture; extracting two nails; puncture, new tube, and patch; fitting two leather shields; replacing outer cover; replacing cover and tube, and changing front near to hind off. *c.* 187 miles to make up.	*a.* Pumping; tyre burst. *b.* Pumping; car troubles; 55·25 miles to make up. *c.* Pumping; tube or tubes changed. *d.* Repairing cover; inflation; attention to front gaiter. *e.* Pumping; nail or stone extracted. *f.* Pumping.	*a.* Nail or stone extracted. *b.* Tightening lace on gaiter; nail or stone extracted. *c.* Drove over 88 paces of uncrushed granite.	*a.* Extracting pin. *b.* Pumping. *c.* Car troubles; 145 miles to make up.	*a.* Pumping. *b.* Taking out inner tube and tightening valve. *c.* Pumping; tyre punctured. *d.* Car troubles; the 118·5 miles to make up run off on Oct. 4.	*a.* Pumping; tube or tubes changed. *b.* Ran only 8 miles owing to greasy roads; 139·5 miles to make up.	*a.* Ran off 75·25 miles arrears viâ Guildford. *b.* Ran off 118·5 miles arrears.	*a.* Made detour of 11·75 miles, allowed for Oct. 8. *b.* Pumping, tyre punctured, and tube or tubes changed. *c.* Nail or stone extracted. *d.* Car broke down near Amersham and towed back.	*a.* Nail or stone extracted; ran only 70·5 miles. *b.* Pumping; tube burst. *c.* Did not run; 117 miles to make up. *d.* Pumping; mended cover; one new cover and inner tube.	*a.* Ran to Hatfield, 39 miles. *b.* Ran to Cole Green, 80·75 miles; changed tube. *c.* Pumping; tube burst; ran to Bishop's Stortford, 50·75 miles. *d.* Did not run.	*a.* Did not run. *b.* Pumping; nail puncture and new tube; ran 155 miles. *c.* Nail extracted; ran to Dorchester, 117 miles.	*a.* Did not run. *b.* Ran 139·5 miles to Maidstone; two punctures and inflation. *c.* Ran to Cole Green, 50·75 miles; Wheatley, 98 miles. *d.* Puncture and patching; ran to Chichester, 145 miles.	*a.* Replacing two tubes.	*a.* Pumping; ran 158·5 miles to Worthing. *b.* Ran 117 miles to Dorchester; puncture, new inner tube, front off cover changed to hind off, reserve cover fitted to front off. *c.* Patching; did not run.	*a.* Pumping; ran 55·25 miles to Bo-Peep Lodge. *b.* Ran to Canterbury; inflation. *c.* Cover and tube changed; total day's run, 60·5 miles	*a.* Did not run.	*a.* This is the revised total.	*a.* Approximate.	

remedying faults, except when delay is not caused by tyres.

HILL CLIMBS: CHATEAU-THIERRY AND

No.	Driver.	Make.	Times. Château-Thierry. M. S.	Gaillon. M. S.	Total. M. S.
	Class I.—Moto-bicycles (under 30 kg.).				
1	Derny	Clément	1 3⅕	1 2⅗	2 5⅘
2	Coudert	Lurquin et Couderd	1 37⅗	1 20⅕	2 57⅘
3	Barret	Bruneau	1 .40	1 24	3 4
	Class II.—Moto-bicycles (30 to 50 kg).				
1	Lambergack	Griffon	0 55⅘	0 49⅘	1 45⅗
2	Demester	—	0 1⅕	0 53⅕	1 54⅖
3	Barrét	Bruneau	1 0⅕	0 59⅕	1 59⅖
	Class III.—Moto-cycles (50 to 250 kg.).				
1	Loste	Buchet	0 49⅕	0 41⅘	1 31
2	Holley	Clément (bicycle)	0 51⅗	0 40⅖	1 32
3	Osmont*	De Dion-Bouton	0 55	0 44⅘	1 39⅘
4	Bourdeaux	Gamet	1 5⅘	0 51⅗	1 57⅖
	Class IV.—Quadricycles (2 seats occupied).				
1	Osmont*	De Dion-Bouton	1 1⅕	0 52⅖	1 53⅗
	Class V.—Voiturettes (250 to 400 kg., one seat occupied).				
1	Thellier	Passy-Thellier	0 58⅕	1 2	2 0⅕
2	Von Latum	Clément	1 14	1 0⅖	2 14⅖
3	Hanriot	Passy-Thellier	1 19	1 14⅘	2 33⅘
4	Combier	Georges Richard	2 4	1 34⅘	3 45⅘

* Used 50 p.c. mixture

RACE: PARIS—MADRID, May 24, 1903 (abandoned at Bordeaux, 565 km.).

First Twelve Cars to arrive at Bordeaux.*

Car.	Driver.	Time. H. M. S.	Car.	Driver.	Time. H. M. S.
Mors	Gabriel	5 13 31	C. G. V.	Voigt	6 1 9·2
Renault	Louis Renault	5 33 59	Mercedes	Gasteaux	6 8 0
Mors	Salleron	5 46 1	Mors	A. Fournier	6 11 39
De Dietrich	Jarrott	5 51 55	Darracq	Baras	6 12 49
Mercedes	Warden	5 56 30·8	Turcat-Méry	Rougier	6 16 7·8
Panhard	De Crawhez	6 1 8·4	De Dietrich	Mouter	6 17 54·2

* 39 heavy cars, 25 light cars, 21 voiturettes, and 13 motor bicycles arrived in addition.

TOWN AND SUBURBAN VEHICLE TRIALS:

Official No.	Make.	Time for Daily Journeys.								
		Nov. 20 (1)		Nov. 21 (2)		Nov. 22 (3)		Nov. 24 (4)		Nov.
		Weight. kilogs.	H. M.	Weight.	H. M.	Weight.	H. M.	Weight.	H. M.	Weight.
	SECTION I.									
	Class I.—Two or four seated carriages, no baggage,.									
7	De Dion-Bouton	—	5 49	1,000	4 51	1,050	5 48	1,050	5 26	1,060
18	Gillet-Forest	—	—	923	4 36	940	4 48	940	4 20	940
16	Clément	970	5 6	952	5 26	976	5 8	976	4 40	976
13	Huber	780	5 54	1,049	5 28	—	—	—	—	—
	Class II.—Four-seated carriage, with baggage accommodation.									
12	Huber	1,373	7 43	1,448	5 16	1,387	5 23	1,387	4 15	1,470
	Class III.—Six-seated carriages, with baggage accommodation.									
8	Gillet-Forest	1,496	4 75	1,520	5 5	1,540	7 57	1,540	5 46	1,634
9	Peugeot	2,012	4 23	1,970	4 34	1,964	5 38	1,964	4 41	1,970
	Class IV.—Delivery vans, carrying 500 to 750 kg. useful load and seat for conductor.									
6	Gillet-Forest	1,476	6 50	1,496	6 27	1,510	6 15	1,510	5 55	1,530
11	Huber	1,344	6 0	1,356	5 55	1,336	5 34	1,336	5 33	1,336
	Class V.— Delivery vans, carrying 300 to 500 kg. useful load and seat for conductor.									
1	Prunel	—	—	1,175	6 29	1,176	5 39	1,176	5 0	1,190
17	Clément	1,635	5 10	1,680	5 36	1,570	6 17	1,570	5 30	1,580
	SECTION II.									
	Class II.— Delivery vans, carrying minimum useful load of one ton and conductor (daily run about 40 km.).									
2	Peugeot	2,800	6 10	2,800	3 51	—	6 4	2,800	6 5	2,800
10	De Dion-Bouton	2,872	6 5	2,635	9 9	2,635	8 12	2,635	8 59	2,554
5	Vinot-Deguingaud	1,980	4 31	1,977	8 23	2,052	6 13	2,052	6 7	2,023
15	Huber	1,877	8 5	1,907	6 0	—	—	1,907	7 20	1,907
	Class III. — Waggons carrying minimum useful load of one ton and conductor.									
3	Peugeot	4,340	5 25	4,490	4 46	4,365	3 14	4,365	3 49	4,365
4	Gillet-Forest	4,850	7 36	4,340	7 35	4,850	7 22	4,850	8 40	4,850
14	De Dion-Bouton	—	8 0	—	10 15	2,780	5 27	2,780	6 54	2,780

Section I.—Hackney Carriages, Station Omnibuses, and Town Delivery

PARIS. NOVEMBER 20 TO 26, 1902.

			Total.	Daily Consumption, Litres.						Total.	Average.
25 (5)	Nov. 26 (6)			1st.	2nd.	3rd.	4th.	5th.	6th.		
H. M.	Weight.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
5 53	1,050	6 22	34 9	7.430	6.750	6.150	5.050	4.980	4.180	34.540	5.756
5 37	953	4 40	21 4	—	6.100	5.670	5.870	5.880	6.020	29.540	5.908
6 3	956	6 34	32 57	11.750	11.700	8.950	10.440	9.830	8.400	61.070	10.178
—	—	—	11 22	8.370	13.460	—	—	—	—	21.830	10.915
4 46	1,488	5 33	32 56	14.000	16.810	12.000	10.780	12.400	11.500	77.490	12.915
6 7	1,483	6 21	36 31	14.300	9.840	7.880	10.610	9.200	9.450	61.280	10.713
4 32	2,010	4 35	28 23	12.950	13.250	15.440	14.870	14.560	15.280	86.350	14.391
6 26	1,514	6 46	38 39	11.400	10.000	8.580	8.700	9.000	8.370	56.050	9.341
5 40	1,354	6 25	35 7	16.400	15.000	15.500	13.750	14.320	14.770	89.740	14.956
5 25	1,194	4 59	27 32	—	9.500	10.840	9.490	8.950	9.325	48.105	9.621
7 45	1,597	6 7	36 25	16.950	12.750	11.500	11.080	10.510	8.830	71.620	11.936
5 16	2,800	6 27	33 53	21.600	14.250	18.300	13.650	13.680	17.000	98.480	16.413
7 40	2,551	8 8	48 13	18.940	17.200	25.900	14.710	13.550	12.500	102.800	17.133
6 45	2,220	6 10	38 9	17.350	16.200	16.650	17.300	16.100	19.110	102.710	17.118
6 37	1,670	6 16	34 18	19.600	15.130	—	17.600	14.500	14.620	81.450	16.290
3 40	4,330	3 25	24 19	16.320	15.000	12.540	13.600	13.420	11.900	82.780	13.796
9 4	4,360	6 51	47 8	25.650	17.790	21.100	21.560	22.100	15.250	123.450	20.573
5 36	2,810	5 33	41 45	15.400	9.700	9.600	11.700	9.380	9.100	64.880	10.813

Vans. Section II.—Suburban Delivery Vans and Waggons.

RELIABILITY TRIALS, AUTOMOBILE CLUB OF GREAT BRITAIN, SEPTEMBER, 1903.

Official No.	General Description.	Passengers, including driver.	No. of cylinders.	Bore.	Stroke.	Brake h.p.	Weight Unladen.	Price.	Sept. 18, 150 miles, Margate.	Sept. 19, 121 miles, Eastbourne.	Sept. 21, 118¾ miles, Worthing.	Sept. 22, 137 miles, Folkestone.	Sept. 23, 144¾ miles, Southsea.	Sept. 24, 121½ miles, Bexhill.	Sept. 25, 133¼ miles, Winchester.	Sept. 26, 91½ miles, Brighton.	Westerham Hill.		Bury Hill.		Hindhead Hill.		Bexhill Speed Trials. Miles per hour.	Handcross Hill. Speed in miles per hour.
																	Time.	Speed in miles per hour.	Time.	Speed in miles per hour.	Time.	Speed in miles per hour.		
	CLASS A1.—*Tandems, Quadricycles, etc., over 170 lb. weight, Selling Price £160 or less.*						Cwt.	£																
1	Century Tandem ..	2	1	88mm.	110mm.	6½	5	125	B	C	B	C	A	B	A	B	—	—	11·11½	4·02	7·45¼	15·47	31·80	13 97
2	6 h.p. Eagle Tandem	2	1	90mm.	110mm.	6	5¾	160	B	C	B	A	C	D	—	—	8·54¾	4·11	5·46½	7·79	9·22¼	12·8	—	—
3	3½-h.p. Rex Tricar..	2	1	3¼ in.	3¾ in.	3½	320 lb.	84	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	CLASS A.—*Cars, Selling Price £200 or less.*						Cwt.																	
4	Baby Peugeot ..	2	1	94mm.	100mm.	5	7	175	B	B	B	B	A	C	A	A	27·45¼	7·70	4·49¾	9·32	7·20	16·36	27·35	10·30
5	6-h.p. Regal.. ..	2	1	90mm.	110mm.	6	8	178/10	A	C	C	C	C	A	C	B	7·43	4·75	10·40¾	4·21	9 32¼	12·58	25·21	9·45
6	6-h.p. Siddeley ..	2	1	4½ in.	5 in.	6	8	175	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	6½-h.p. Century, two-seater	2	1	88mm.	110mm.	6½	9	200	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	7-h.p. Vesta	2	1	100mm.	120mm.	7	8	160	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	6½-h.p. Vulcan ..	2	1	4 in.	4 in.	6½	10	175	B	C	G	—	—	—	—	—	14·31¾	2·52	—	—	—	—	—	—
10	6-h.p. Wolseley light car	2	1	4¼ in.	5 in.	6	9	175	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11	Stanley (steam) ..	2	2	2½ in.	3¼ in.	5½	9	194/5	C	C	C	C	C	B	B	A	38·14¼	·95	8·10½	5·50	7·48¾	15·37	32·14	14·24
12	5-h.p. Coventry Humberette ..	2	1	3¾ in.	3½ in.	5	5¼	131/5	B	B	C	A	C	C	D	—	13·51¼	2·80	8·6½	5·54	17·44½	6·76	19·07	—
13	5-h.p. Beeston Humberette	2	1	3¾ in.	3¾ in.	5	5½	147	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	6½-h.p. Cadillac ..	2	1	5 in.	5 in.	6½	1,250 lb.	200	A	E	B	C	A	A	A	A	—	—	5·43	7·87	10·48½	11·1	28·75	9·80
							Cwt.																	
15	Pony Richard ..	2	1	90mm.	100mm.	5½	—	185	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	6-h.p Relyante ..	2	1	20mm.	110mm.	6	8¼	168	G		—	—	—	—	—	—	—	—	—	—	—	—	—	—
17	5-h.p. Oldsmobile ..	2	1	4¾ in.	6½ in.	6	7	150	B	C	C	B	A	A	C	C	—	7·55	5·56	7·58	8·55	13·45	24·85	9·78
18	6½-h.p. Clyde ..	2	1	90mm.	110mm.	6¾	7¾	175	B	C	A	C	A	B	A	C	22·11½	1·65	5·33¾	8·00	10·44½	11·16	31·69	11·82
19	6-h.p. Elswick ..	2	1	100mm.	110mm.	6	8	200	C	F	C	C	C	B	A	A	—	4·38	6·17½	7·14	13·13½	9·97	23·13	10·02
20	6-h.p. De Dion Bouton	2	1	90mm.	110mm.	6	8	200	D	C	B	B	A	C	B	A	6·5½	6·02	6·30¾	6·91	8·36½	13·23	27·86	12·21
21	5-h.p. Oldsmobile ..	2	1	4¾ in.	6 in.	5	7	150	B	C	A	B	C	B	B	A	6·49¾	5·37	6·16½	7·17	11·19¾	10·59	27·77	11·56
22	7-h.p. Cottereau ..	2	1	105mm.	118mm.	7	9	195	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	8-h.p. Achilles ..	2	1	100mm.	110mm.	8	11	175	C	C	C	C	C	C	C	C	6·1	6·09	6·7	7·35	8·7	14·78	19·87	23·00
	CLASS B.—*Cars, Selling Price £200—£300.*																							
24	6-h.p. Swift	2	1	90mm.	110mm.	6	10	220/10	A	B	C	C	A	A	A	A	4·31½	8·09	5·49¾	7·71	7·29	15·68	22·00	9·76
25	8 to 10-h.p. Regal ..	5	2	98mm.	125mm.	10	15	300	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26	7-h.p. Coronet ..	2	1	125mm.	110mm.	7	9·5	250	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
27	10-h.p. Century ..	4	2	88mm.	110mm.	10	15	300	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28	9-h.p. Beaufort Tonneau	4	1	110mm.	120mm.	9	13	295/10	C	A	B	A	A	A	C	C	5·46½	6·35	6·38¾	6·77	8·18½	14·45	29·12	8·38
29	9-h.p. Argyll .	4	1	100mm.	120mm.	9	12	275	B	B	B	C	A	A	A	A	5·30½	6·53	6·30½	6·14	9·7½	13·15	26·08	9·35
30	10-h.p. Pick Tonneau	4	2	4½ in.	4½ in.	10	19	290	H	—	—	—	—	—	—	—	—	—	—	—		—

31	10-h.p. Pick Voiturette, with dickey seat	3	2	4½ in.	4½ in.	9	17	270	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
32	9-h.p. Mathieu ..	4	1	110mm.	130mm.	9	13	300	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
33	9-h.p. Renault ..	4	1	100mm.	120mm.	9	13½	300	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
34	10-h.p. Georges Richard	2	2	100mm.	100mm.	10	11½	300	A	B	A	C	D	—	—	—	3·39⅗	10·02	3·59⅗	11·26	7·4	16·98	—	—
35	9-h.p. Eagle .. .	2	2	85mm.	110mm.	9	9	235	C	C	B	C	A	C	A	A	4·12⅕	8·72	5·7⅕	8·77	7·37⅗	15·74	26·47	10·48
36	10-h.p. Rex .. .	4	1	4¼ in.	4½ in.	10	15	278/5	C	C	C.	A	D	—	—	—	13·56⅕	2·63	9·2⅕	4·98	13·41⅘	8·74	—	—
37	4-h.p. Roots (paraffin)	2	1	4½ in.	5 in.	4	11	260	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
38	9-h.p. Mohawk Manon	4	1	100mm.	120mm.	9	12	210	A	B	C	C	C	C	A	A	8·48⅗	4·16	6·59⅕	6·44	8·38	13·9	23·19	13·47
39	8-h.p. M.M.C. ..	4	1	110mm.	130mm.	8	11½	270	A	B	A	A	A	A	A	A	5·46	6·36	6·48⅘	6·60	8·32	14·06	29·50	9·29
40	9-h.p. Darracq ..	4	2	90mm.	100mm.	9	12¾	300	C	A	C	A	C	B	C	A	8·12	4·47	7·54⅕	5·69	13·27⅘	8·91	22·85	6·81

Class C.—*Cars, Selling Price £300—£400.*

41	10-h.p. Gladiator ..	4	2	105mm.	130mm.	10	14¾	395	A	B	C	A	A	C	B	C	4·9⅕	8·81	4·84	10·85	6·28⅗	18·51	34·88	15·33
42	12-h.p. Albion ..	4	2	4¼ in.	5 in.	12	22	363	B	A	A	A	A	A	B	A	6·23	5·74	7·39	5·88	10·8	—	20·93	8·64
43	10-h.p. Hallamshire	4	2	105mm.	120mm.	10	15½	325	C	C	C	C	C	C	C	A	7·1⅕	5·21	6·5⅗	7·38	14·21⅘	8·35	21·53	5·75
44	8-h.p. Standard ..	4	1	5 in.	3 in.	8	13	330	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
45	12-h.p. Arrol-Johnston Dogcart	4	2	4½ in.	6 in.	12	25	360	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
46	7-h.p. Star	4	2	4 in.	5 in.	9	14½	350	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
47	9-h.p. James and Browne	4	2	4 in.	6 in.	9	17	400	A	A	A	A	C	C	C	B	5·47	6·34	8·12⅗	5·48	9·38⅗	12·44	28·03	—
48	10-h.p. Argyll ..	4	2	88mm.	120mm.	10	13	335	A	A	A	A	A	A	A	A	5·5⅘	7·20	5·19⅕	8·45	8·1⅕	14·96	29·50	7·57
49	14-h.p. Argyll ..	4	3	90mm.	120mm.	14	14½	400	B	B	A	D	—	—	B	B	20·0	1·83	4·58⅘	9·04	—	—	—	7·86
50	10-h.p. Simms Welbeck	4	2	95mm.	110mm.	10	13½	360	C	B	C	C	C	D	—	—	7·36⅗	4·81	7·49⅗	5·80	13·37⅘	8·32	—	—
51	12-h.p. Wolseley ..	4	2	4½ in.	5 in.	12	19	400	A	A	A	A	A	A	A	A	4·13⅗	8·68	4·37⅗	9·73	6·17⅕	18·56	31·48	15·51
52	10-h.p. Wolseley ..	4	2	4¼ in.	5 in.	10	19	380	A	B	A	A	A	A	A	A	3·46⅗	9·72	3·58⅕	11·31	6·42⅕	17·87	32·84	15·51
53	12-h.p. Century ..	4	2	105mm.	130mm.	12	17	400	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
54	12-h.p. Krupkar ..	4	2	115mm.	120mm.	12	15	400	C	C	C	D	—	—	—	—	—	—	—	—	—	—	—	—
55	9-hp. Humber ..	4	3	3½ in.	4½ in.	9	14	400	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
56	10-h.p. Horbick ..	4	2	4⅛ in.	4¾ in.	10	17¾	399	A	A	A	C	C	C	C	B	5·46⅗	6·35	6·51⅗	6·55	9·57⅕	12·04	23·49	9·78
57	12 h.p. Georges Richard	4	2	101mm.	100mm.	12	13¾	385	A	B	A	B	A	A	A	A	5·31⅗	6·97	5·53⅗	7·64	9·50⅗	12·18	26·86	9·22
58	12-14-h.p. Relyante	4	2	100mm.	140mm.	12	15	367/10	C	C	B	A	C	A	A	A	7·22⅗	4·97	5·52⅕	7·66	10·27⅕	11·47	30·50	9·07
59	13-h.p. Rex	4	2	4¼mm.	4½ in.	13	16½	367/10	A	C	A	C	A	B	B	A	7·39⅗	4·79	5·24⅗	8·31	8·2⅗	14·92	33·08	13·06
60	10-h.p. Déchamps ..	4	2	100mm.	140mm.	10	16¾	375	C	C	A	B	B	A	A	B	11·27⅗	3·20	6·41⅕	6·73	10·44⅕	11·17	23·87	9·23
61	10-h.p. Ryknield ..	4	2	3½ in.	4½ in.	9	14	350	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
62	7½-h.p. Wolseley ..	4	2	4 in.	4 in.	7½	15	325	C	A	A	A	A	A	A	A	4·46⅗	7·67	5·1⅗	8·95	7·22	16·25	32·84	10·15
63	10-h.p. Spyker ..	4	2	100mm.	120mm.	10	13	380	C	A	C	B	A	A	A	A	5·12⅗	7·04	5·30⅗	8·17	10·5⅗	11·89	21·42	9·65
64	12-h.p. Darracq ..	4	2	100mm.	120mm.	12	15¾	350	B	C	A	A	B	A	B	A	5·9⅗	7·10	5·35⅗	8·04	8·31⅗	13·92	29·22	10·44

Class D.—*Cars, Selling Price £400—£550.*

65	12-h.p. Sunbeam ..	4	4	80mm.	120mm	12	15 to 16	525	C	C	A	A	A	A	A	A	4·22⅗	8·38	5·4⅘	8·87	8·7⅕	14·76	33·33	11·40
66	12-h.p. Gladiator ..	4	4	88mm.	110mm.	12	15½	540	B	C	C	C	C	A	A	A	3·52	13·22	3·21⅗	13·39	5·30⅗	21·79	41·45	20·68
67	12-h.p. Ariel ..	4	4	3½ in.	3½ in.	16	17	550	G	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
68	14-h.p. Brooke ..	4	3	3¾ in.	4⅜ in.	14	18	500	B	B	B	B	C	B	A	A	4·47⅕	7·64	5·7⅗	8·78	7·47⅗	15·39	27·60	10·79
69	16-h.p. Okodyne (steam)	4	3	3¾ in.	4½ in.	9	21	405	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
70	10-h.p. Thornycroft	4	2	4 in.	4¾ in.	10	15	440	B	C	A	A	A	A	C	C	9·19⅗	3·93	6·49⅗	6·59	10·17⅗	11·66	24·00	7·51
71	10-h.p. Peugeot ..	4	2	105mm	105mm.	10	—	450	A	C	B	A	A	A	A	A	15·34⅗	2·35	7·21⅕	6·11	8·12⅕	14·62	32·14	12·00
72	20-h.p. Hallamshire	4 or 6	4	105mm.	120mm.	20	19	450	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

A, non-stop run; B, run completed with delays involving loss of 5 marks or less; C, loss of more than 5 marks; D, retired from day's journey; E, re-ran this route; F, retired, but reinstated in trials; G, withdrawn from trials: H, did not take part. (Judges' awards not announced at time of going to press.)

RELIABILITY TRIALS, AUTOMOBILE CLUB OF GREAT BRITAIN, SEPTEMBER, 1903 (*continued*).

Official No.	General Description.	Passengers, including driver.	No. of cylinders.	Bore.	Stroke.	Brake h.p.	Weight Unladen.	Price.	Sept. 18, 150 miles, Margate.	Sept. 19, 121 miles, Eastbourne.	Sept. 21, 118¾ miles, Worthing.	Sept. 22, 137 miles, Folkestone.	Sept. 23, 144¼ miles, Southsea.	Sept. 24, 121¾ miles, Bexhill.	Sept. 25, 188¾ miles, Winchester.	Sept. 26, 91¾ miles, Brighton.	Westerham Hill.		Bury Hill.		Hindhead Hill.		Bexhill Speed Trials. Miles per hour.	Handcross Hill. Speed in miles per hour.
																	Time.	Speed in miles per hour.	Time.	Speed in miles per hour.	Time.	Speed in miles per hour.		
	Class D.—*Cars, Selling Price £400—£550 (continued).*																							
							Cwt.	£																
73	Cremorne (steam, paraffin)	4	4	3¾ in.	4 in.	12	25	500	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
74	12-h.p. Arrol-Johnston, six-seater	6	2	4½ in.	6 in.	12	27	420	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
75	8 to 10-h.p. Elswick	5	2	110mm.	130mm.	8 to 10	15	472/10	C	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—
76	16-h.p. Century ..	4	4	88mm.	110mm.	16	19	500	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
77	10-h.p. Star	4	4	3¼ in.	4½ in.	12	17	550	A	B	A	B	A	A	A	A	3·46⅘	9·71	4·22⅗	10·28	6·43⅕	17·85	39·45	13·74
78	14-h.p Beaufort Tonneau	4	2	110mm.	125mm.	14	16	417/15	C	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—
79	16-h.p. Argyll ..	4	4	88mm.	110mm.	16	16	550	A	C	A	C	C	A	A	A	3·55	9·36	4·51⅗	9·25	6·17⅗	19·06	34·48	12·55
80	15-h.p. Belsize ..	4	2	4 in.	5 in.	15	17½	455	A	C	G	—	—	—	—	—	4·31⅗	8·09	5·32⅕	8·11	—	—	—	—
81	12-h.p. Belgica ..	4	2	120mm.	140mm.	15	17	430																
82	14-b-h.p Brooke ..	4	3	3¾ in.	4½ in.	14	19	500	C	B	B	A	C	A	C	G	5·16	6·92	4·45⅗	9·46	—	—	32·72	—
83	10-h.p. Relyante (steam, paraffin)	3	4	2¾ in.	3 in.	10	18	472/10	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
84	10-h.p. White (steam)	4	2	3in.h.p. 5in. l.p.	3¼ in.	10	15	420	C	A	A	B	B	A	A	B	4·18⅘	8·50	3·18	13·63	7·53⅘	15·2	33·58	10·42
85	12-h.p. Dennis ..	4	2	105mm.	130mm.	12	19	420	A	B	C	C	A	C	A	A	10·26⅕	3·51	6·11⅗	7·26	8·7⅗	14·77	31·57	10·42
86	12-h.p. Clement ..	4	4	75mm.	120mm.	12	14½	550	A	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—
87	10-h.p. Lanchester..	4	2	5¼ in.	5½ in.	10	19½	525	B	B	A	A	A	A	A	A	5·27	6·73	5·39⅕	7·96	8·7⅗	14·76	33·21	9·11
88	12-h.p. Sunbeam ..	4	4	80mm.	120mm.	12	16	525	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
89	12-h.p. Brush ..	4	4	85mm.	118mm.	14	18	500	B	A	C	A	C	B	C	A	3·52⅘	9·45	4·40⅗	9·62	6·30⅕	18·45	31·57	12·37
90	16-h.p. Maxim ..	4	2	110mm.	120mm.	16	—	472/10	C	C	B	C	C	A	C	A	4·22⅕	8·37	4·46⅕	9·43	6·22⅘	18·8	30·10	11·45
91	12-h.p. De Dion-Bouton	4	2	100mm.	110mm.	12	14	420	A	A	A	A	B	A	A	B	2·57⅗	12·40	3·40⅗	12·22	5 12⅕	23·06	36·53	15·81
92	12-h.p. New Orleans	4	4	95mm.	110mm.	12	17	500	A	A	C	A	C	A	A	A	2·57	12·43	3·36⅘	12·45	5·23⅘	22·23	39·30	15·78
93	10-h.p. Renault ..	4	2	100mm.	110mm.	10	13	437	B	A	A	A	A	A	A	A	4·13⅗	8·67	4·55⅘	9·14	7·10⅖	15·64	32·02	13·63
	Class E.—*Cars, Selling Price £550—£700.*																							
94	20-h.p. Thornycroft	5	4	4 in.	4½ in.	20	17	640	B	C	B	C	A	A	A	A	6·26⅗	5·70	3·52	11·63	8·11	14·66	39·30	15·33
95	12-h.p. Chelmsford (steam, paraffin)	6	2	4 in.	4 in.	12	28	620	A	C	B	A	C	C	A	C	7·59⅗	4·58	6·34⅗	6·84	8·16⅗	14·49	31·91	16·57
96	15-h.p. Germain ..	4	4	95mm.	130mm.	15	18	700	C	B	A	C	B	C	A	A	4·31⅗	9·04	3·57⅗	11·36	6·32⅕	18·35	33·08	11·90
97	15-h.p. New Orleans	4	4	100mm.	110mm.	15	19	561/15	A	A	A	C	B	A	A	C	3·20⅕	10·96	3·22	13·36	5·11	23·15	40·51	17·24
98	16 to 20-h.p. Elswick	5	4	110mm.	130mm.	16to 20	17	682	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
99	15-h.p. Star	4	4	4 in.	4½ in.	18	18	600	B	D	—	—	—	—	—	—	—	—	—	—	—	—	—	—
100	18-h.p. James and Browne	4	4	4 in.	6 in.	18	18	650	B	B	B	A	B	A	A	A	4·11⅕	11·52	4·12⅗	10·68	4·47⅘	25·04	40·35	20·68
101	20-h.p Simms Welbeck	4	4	95mm.	110mm.	20	16	625	H	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
102	24-h.p. Wolseley ..	4	4	4½ in.	5 in.	24	23	660/5	A	A	B	A	A	A	B	A	2·28⅕	11·70	2·43	10·52	5·01	23·03	11·00	19·02

CONSUMPTION TRIALS. SURESNES—CORBEIL AND BACK (100 KM.), FEBRUARY, 1903.

Official No.	Make.	H. P.	Gross Weight in kg.	Carburetter.		Consumption in Litres.		Time.
						Gross.	Ton-km.	H. M. S.
	Voiturettes.							
41	De Dion-Bouton	6	600	De Dion-Bouton		4·400	0·0733	4 55 44⅗
42	,,	6	580	,,		4·440	0·0764	4 59 49⅖
31	De Boisse	3	340	Longuemare		5·500	0·160	5 12 9
44	De Dion-Bouton	6	600	De Dion-Bouton		5·850	0·0975	5 17 26⅘
38	Européenne	6	572	,,		11·350	0·216	3 7 22⅕
	Light Cars.							
33	Peugeot	6½	969	Peugeot		5·200	0·0536	4 11 22⅕
32*	,,	6½	900	,,		5·720	0·0635	5 25 21
34	,,	6½	890	,,		5·950	0·0668	3 42 17⅗
3	Gillet-Forest	5	880	Sthenos		6·500	0·0738	4 47 39⅗
11*	Automotrice	9	730	Longuemare		6·720	0·0920	4 20 12
50	Herald	8	1,640	,,		8·600	0·134	3 26 3⅘
18	Impetus	12	—	,,		†19·	—	3 59 14⅕
	Cars.							
16	Chenard & Walcker	10	1,160	Longuemare		6·290	0·0542	4 29 59⅘
23	Bardon	5	897	Le Blon		6·540	0·07257	5 40 33⅕
17	Chenard & Walcker	10	1,180	Longuemare		7·250	0·0614	4 18 33
24	Bardon	8	1,135	S.A.T.		7·350	0·0647	4 7 58⅗
2	Gillet-Forest	12	920	Gillet-Forest		7·700	0·0836	4 25 11⅗
40*	Hurtu	9	860	Longuemare		7·770	0·0902	5 17 23
15	Chenard & Walcker	10	920	,,		8·340	0·09067	5 56 26⅘
51	L'Enviable	12	870	,,		·800	0·101	5 4 25⅕
39	Hurtu	10	1,100	,,		9·160	0·0832	3 40 3⅘
37	Herald	12	1,150	,,		9·700	0·0842	5 57 23⅘
36	,,	12	1,175	,,		10·650	0·09064	5 32 40⅕
56	Regina	16	1,300	Regina		10·750	0·0825	5 12 15⅕
49	Abeille	10	1,200	Abeille		11·770	0·098	—
28	Vinot-Deguingaud	18	—	Longuemare		13·600	—	4 25 50⅘
30	Turcat-Méry	12	1,360	Turcat-Méry		14·300	0·106	3 16 33⅕
	Heavy Cars.							
25	Bardon	8	1,200	S.A.T.		7·110	0·0592	5 3 46⅗
19	Mors	8	1,205	Mors		8·600	0·0713	4 38 56⅘
21	,,	10	1,540	,,		11·170	0·07254	5 45 56
22	,,	15	1,290	,,		11·430	0·088	4 47 18⅘
20	,,	8	1,330	,,		†18·700	0·140	6 2 8
	Industrial Vehicles.				Useful Weight carried in kg.	Gross.	Ton-kilom.	H. M. S. for 60 km.
1	Gillet-Forest	6	1,660	Sthenos	910	8·700	0·0873	5 28 36⅕
54*	Prunel	8	1,310	Longuemare	525	13·610	0·103	5 10 20⅕
26	Bardon	5	2,335	Le Blon	1·540	6·960	0·0496	4 39 34⅕
35	Peugeot	12	4,680	Peugeot	2·900	13·750	0·0489	4 29 27⅕
14	Sage	10	2,575	Sage	1·364	11·	0·0714	5 39 12⅗

* 50 per cent, alcohol mixture, all other vehicles used petrol. † Leaking reservoir.

CHAPTER XXIII.

APPLICATIONS, EFFICIENCY, AND FURTHER PROGRESS OF THE AUTOMOBILE.

FOLLOWING after the instructive records just given, this chapter may well be concerned with a review of the special applications of the three agents of mechanical road locomotion—steam, petrol, and electricity.

Steam cars, as has been said, are more rapid than, but not yet as cheap as, horses for conveyance of ordinary goods, though they can provide regular passenger services on good roads with greater comfort and much more quickly than horses, and still leave a certain profit for the contractors; in fact, a number of such services has been established. The relative costs of horse and steam traction must vary with the nature of the work required to be done; and in the carriage of heavy materials in continuous jobs it is quite probable that steam cars would prove cheaper than horses.

The recent great development and the remarkable progress of heavy steam cars in England are recorded in Chapter XVII., whilst the tables in Chapter XXII. show excellent performances of these types of cars. These are no longer experimental vehicles, and their convenience, economy and reliability are being recognised more and more. Motor traction is well adapted for carrying supplies to forts, etc., and for the transport of other heavy war material.

The light steam runabout car typified by the Locomobile, Toledo, Weston and other American productions has made astonishing progress during the past year or so, and its worth has been proved again and again under the most severe conditions of road traction. Records of what it has accomplished have been given already. Perhaps, however, there is more interest in the more complicated vehicles, such as the Gardner-Serpollet, White, Chaboche, and Miesse cars, which are still in a state of development, although they have already done highly satisfactory service. There is no doubt that steam is now a formidable and progressive rival of petrol for road locomotion.

The petrol tricycle and quadricycle, made accessible by their comparatively low price, are by far the most commonly employed automobiles if bicycles are ignored; and they are both serviceable and durable. There is no doubt, however, that the motor bicycle has made a successful bid for popularity, and will have a marvellous future. It is cheap, and as a rule serviceable, and its reliability becomes a matter of greater certainty as time goes on.

The petrol car is the best form of touring car; it enables very long journeys to be made at comfortable speeds and moderate cost. Compulsory stoppages usually are of short duration, and their number, excepting those for repairing tyres, is very small. Tyre troubles are the great bugbear, but even these are diminishing. The very greatest service can be rendered to the industry by the promotion of tyre trials, such as the one recorded on pp. 794 and 795.

Already the petrol car is employed on an extensive scale, and its progress has been and will be very rapid. The light car or voiturette has rendered good service. Big and high-powered cars are expensive in price, repairs, and consumption, and consequently remain too much in the hands of rich persons. Numerous buyers could be found for a vehicle with two places, weighing hardly 300 kg. (660 lb.) empty, running from 20 km. to 25 km. (12·4 miles to 15·5 miles) per hour, and costing only £120. Unfortunately, low prices are more difficult in such a case than in that of a large car, owing to the useful load bearing such a big proportion (nearly one-half) to the dead load, whereas it is often only one-third or a quarter in the larger car. But still, in the 1903 Reliability Trials (the judges' awards in which are awaited as this work goes to press) there are twenty cars declared at a selling price of less than £200, and manufacturers are doing their best to meet the need for a cheap and trustworthy light petrol car. The miniature Velox, sold at £125 and weighing 203 kg. (4 cwt.), is an example of what can be done in this direction.

Dispensing with water-cooling would simplify the structure of the car, but there is not much hope of this being accomplished yet awhile. The Lanchester system of air-cooling has proved successful, however, and there may be a possible general solution of the difficulty along that line.

Though petrol motors did not appear to be suitable for heavy goods vehicles, the Milnes' petrol lurry, the de Dietrich petrol lurry, and some German lurries have raised great hopes of what may yet be effected; at any rate, they can be employed for average weight vehicles of this kind. In England the petrol car is coming into use for light goods delivery work, but the heavier vehicles—the Milnes lurry being almost the only exception—are steam-driven.

Electric cars have a great future, but some initial difficulty has to be overcome, especially as regards electric cabs for public service; but the difficulties are much less in the case of livery or private carriages, which afford the greatest scope for the development of the electric car. In any case, its future seems assured. According as accumulators are made lighter, more durable, and their charging easier, the electric car will find its field of action greatly increased, for already it is the cleanest and most comfortable system of road locomotion. The wide and rapid growth of electrical applications in America seems to point to that country as having the greatest scope for the development of the electric automobile.

As an instance of what an electric automobile was capable of even a year or so ago, it may be said that the Comte de Chasseloup-Laubat travelled from Paris to Rouen, a distance of 128 km. (79·5 miles), the journey taking 7 hrs. 15 mins. During the journey the accumulators were not touched, and he returned the same day to Paris in 7 hrs. 32 mins. after recharging them at Rouen. This car was not built for long journeys, but rather for average ones at full speed; it was, in fact, the Jeantaud car with which de Chasseloup-Laubat had made a kilometre record at Achenes. The car weighed 2,250 kg. (4,950 lb.) with its two passengers and 80 Fulmen type B_{17} elements. In America a car weighing 1,132 kg. (2,490·4 lb.) with its two passengers and 448 kg. (985·6 lb.) of accumulators, has run 161 km. (100 miles), without recharging, in 7 hrs. 45 mins.—that is, at the rate per hour of 21 km. (13 miles).

What effect the petrol-electric car will have can only be surmised, but that it will have a great influence on automobilism in general is well nigh certain. A statement with regard to the position of the petrol-electric car in relation to other traction systems is given on p. 347.

Increased efficiency is one of the objects towards which constructors should aim, for if the automobile is to find its way into more general practice, and more especially commercial quarters, its consumption must be lessened. To demonstrate this, it will be useful to begin by theoretically calculating what the efficiency may be for each of the three agents commonly employed.

The thermal efficiency of a steam motor is the ratio of the number of units of heat really used on the piston to the number of units represented by the fuel burnt. This thermal efficiency is itself the product of two factors. One factor is the efficiency of the boiler, this being the ratio of the number of heat units employed to vaporise the water to those which existed in the fuel employed; this ratio is from 70 to 80 per cent., 30, or at least 20, per cent. of the units being lost, either with the particles which pass through the fire grate without being perfectly consumed, or with the smoke which carries away some of the heat. The second factor is the internal efficiency of the motor; this is the ratio of the work actually gathered by the piston to that amount of work theoretically equivalent to the heat employed to produce the steam; this ratio is from 15 to 20 per cent., 85, or at least 80, per cent. of the heat from the water, therefore, being wasted, either because it remains latent and is not transformed into work, or because pressure is not usefully exerted on the piston.

The organic efficiency of the motor is the ratio of the work gathered by the shaft to that received by the piston; also this is called indicated work, because it is that recorded by pressure gauges; this ratio is equal to 70 or 80 per cent., 30, or at least 20, per cent. of the work gathered by the piston thus being wasted by the connecting rods and cranks that unite piston and shaft. Therefore, to obtain the efficiency of the motor—that is, the ratio of work gathered on the shaft to the work represented by the heat units of the fuel employed—the product of the three elementary efficiencies just defined must be found. Taking for each of these the average of the values above given, the average efficiency proves to be $(0{\cdot}750 \times 0{\cdot}175 \times 0{\cdot}750) =$ nearly 0·1—that is, 10 per cent. Dwelshauvers-Dery estimates that an efficiency of 15 to 16 per cent. can never be exceeded by a steam-engine, whatever may be the improvements attempted in the fire-box, boiler, motor, and transmission gear to shaft. In any case, the greatest efficiency hitherto attained is 13 per cent., which corresponds to a consumption of 650 g. (22·9 oz.) of coal burnt in the fire-box per effective horse-power hour collected on the motor shaft. Consumption has been reduced thus only with very powerful engines furnished with all the latest improvements, such as superheated steam, multiple expansion, energetic condensation. With engines of slight power and designedly simplified, like those of automobiles, so small a consumption cannot be reckoned on. Adopting 1·5 kg. (3·3 lb.) as the consumption per effective horse-power-hour (this was realised in de Dion-Bouton motors), the efficiency of an automobile motor is $\left(0{\cdot}13 \times \frac{0{\cdot}650}{1{\cdot}500}\right) = 0{\cdot}056$—that is, roughly, 5 per cent.

The efficiency of the car itself is found by multiplying the available work on the motor shaft by the transmission efficiency, this giving the work available at the wheel tyre. The efficiency of the petrol car transmissions tested at Chicago was not more than 50 per cent. De Witz states that it varies from 40 to 75 per cent., the average being 50 per cent. With steam vehicles, which have simple transmission gear, it may be estimated at 60 per cent., and perhaps 70 per cent. if, as is sometimes admitted, the absence of an intermediary shaft decreases the loss in transmission by 10 per cent. Taking the highest figures, the final efficiency of a steam car—that is, the ratio between the energy utilised at the tyre and the potential energy of combustion—is only 3·92 per cent. This is really miserable.

In dealing more in detail with the efficiency of petrol cars, there is no need to repeat much of what already has been said in dealing with steam. In the two elementary factors of the thermal efficiency the boiler efficiency has to be replaced by that of the combustion, which is simply the ratio of the number of calories disengaged by the combustion of the carburetted mixture to the calories represented by the fuel.

It may be said at once that 20 per cent. can be considered the heat efficiency of the petrol motor. This is greater than in the steam-engine, and is partly due to the fact that combustion of petrol takes place in the cylinder itself, whereas the coal is burnt in a fire-box under very unsatisfactory conditions. Another point is that the temperature attained by the gases produced by the combustion is much greater than that of steam (1,500° to 1,800° C., instead of 200° C. (2,732° to 3,272°, instead of 392° F.), and the Carnot theorem demonstrates that the economic efficiency of the motor increases with this temperature. However, automobile petrol motors do not realise an efficiency of 20 per cent. A Daimler motor of 2 to 4 h.p. gave Prof. Hartmann a thermal efficiency of 11 per cent. and an organic efficiency of 9·7 per cent. These figures about agree with those deduced from the Chicago trials. Basing himself upon them, R. Soreau fixes the average consumption of petrol spirit at 0·870 kg.—that is, 1·25 l. (30·6 oz., or 2·2 pints) per horse-power hour available on the motor shaft, which is equivalent to a thermal efficiency of from 9 to 10 per cent. and an organic efficiency of 7·3. Since the date of these experiments (Nov., 1895) the construction of petrol motors has much improved, and their thermal efficiency attains, pretty regularly, 16 per cent., this corresponding to an organic efficiency of about 13 per cent. and a consumption of about 500 g., or 0·7 l. (1·1 lb., or 1·23 ps.), per effective horse-power hour on the motor shaft.

Full data as to the consumption of modern motors are given on pp. 783, 784, 787 and 792 of the previous chapter.

Invention of the Diesel motor has greatly increased the efficiency of internal combustion motors. Diesel maintains that theoretically the consumption should fall to 112 g. (3·95 oz.) per indicated horse-power hour, which would correspond to a thermal efficiency of 75 per cent. In any case, it has been shown that the 20-h.p. Diesel motor has given 34 to 35 per cent. in full charge, 38 to 40 per cent. half charge as thermal efficiency, and 75 and 59 per cent. as mechanical efficiency, which brings the total for effective efficiency to 25 per cent. in full charge and 22 per cent. half charge. The corresponding consumption of petrol spirit is 240 g. (8·46 oz.) per horse-power hour on the shaft for full charge and 277 g. (9·76 oz.) for half charge. Hitherto the best stationary petrol engines have consumed from 300 g. to 400 g. (10·58 oz. to 14·1 oz.). Thus the desirability of the adoption of the Diesel motor for cars is evident.

For the efficiency at the tyres of the road wheels the total efficiency of the motor (taken as 13 per cent.) must be multiplied by that of the transmission, namely, 50 per cent. Therefore, not more than 6 or 7 per cent. of the energy of the petrol spirit is actually turned to account, and from 93 to 94 per cent. is wasted; this is not much better than with steam.

With regard to electric automobiles, it is assumed that the electricity is generated in works, as is usually the case, provided with improved steam engines whose efficiency can be taken as 10 per cent. The efficiency of the dynamo—that is, the ratio of the mechanical work supplied to it to the electric energy it produces—should be 75 per cent. at least, 80 per cent. according to Hospitalier. The efficiency of the accumulators cannot be taken as more than 75 per cent., and that of the electric motor which they run is at least 75 per cent.; according to Hospitalier the electric motor efficiency is from 80 to 88 per cent., the average being 84 per cent. The efficiency of the transmission gear from the electric motor to the wheels according to the Chicago trials may be estimated at 70 per cent., though Hospitalier says 90 per cent. The final efficiency (ratio of energy at the wheel tyres to that of the coal burnt in the fire box of the steam engine driving the generating dynamos at the charging works) is 3·9 per cent. at the lowest and 4·5 per cent. according to Hospitalier. This efficiency occupies a place between steam and petrol. However, electricity makes it possible to employ water power, a natural power which costs hardly anything, instead of costly coal. It may be remarked that the cost of current constitutes only a small item in the cost of electric locomotion.

The efficiencies just worked out are deplorable, but yet these are scarcely exceeded in practice and are even rarely attained. From an experiment which lasted eight months and dealt with a distance of 7,700 km. (4,784·6 miles), Michelin considered that for a de Dion-Bouton steam brake with six places, weighing 2,050 kg. (4,510 lb.) when loaded ready for the road, the average speed per hour being 16 km. (9·9 miles), the kilometric consumption might be fixed at ·55d. worth of coke; at £1 8s. per ton this means 1·75 kg. (3·85 lb.), equivalent to 13,125 calories (51,052 B.H.U.) and 5,578,125 kgm. (nearly 40,350,000 ft.-lb.). Now according to the published tables of Julien and Boramé, the useful effort that is exerted tangentially at the tyre on a level at an hourly speed of 16 km. (9·9 miles) is 90 kg. (198 lb.) for a car of 2,500 kg. (5,500 lb.). Thus the number of kgm. (7·23 ft.-lb.) expended per km. (·62 mile) is 90,000 and the efficiency at the tyre $\frac{90{,}000}{5{,}750{,}125} = 0{\cdot}016$, that is 1·6 per cent. That is on the level; considering the road to have a continuous rising gradient of 4 per cent., in this case the tangential effort would be 190 kg. (418 lb.) instead of the 90 kg. on the level. The efficiency then would be twice as great, namely, 0·032, or 3·2 per cent., but this is less than the value calculated. It need not be remarked that the brake has not always to run under full charge, and that under ordinary conditions it has not by any means to travel along a road with an average gradient of 4 in 100.

Petrol gives better results. A catalogue dated April 15th, 1898, published by the Peugeot firm, gives 0·57d. to 0·855d. as the cost of running a car with a 4 to 6 h.p. for a kilometre. Reckoning petrol spirit at 3·8d. per l. of 700 g. (17·3d. per gall. or 2·46d. per lb.) the 0·855d. given by the Peugeot firm corresponds to 157 g. (5·5 oz.), which, admitting a power of 11,000 calories, represents $0{\cdot}157 \times 11{,}000 = 1{,}727$ calories and $(1{,}727 \times 425)$ 733,975 kgm. (about 5,309,000 ft.-lb.). Suppose that the 6-h.p. car weighs one ton with passengers and runs 30 km. (18·64 miles) per hour on a level; the corresponding tangential effort is 51 kg. (112·2 lb.); therefore the work expended is 51,000 kgm. (nearly 369,000 ft.-lb.) per km. (·62 mile), and the efficiency $\frac{51{,}000}{733{,}975}$ is a little less than 7 per cent. Other and more modern examples can be worked out from the data given in the previous chapter.

Concluding remarks can have for their subject the progress to be aimed at. Of the first importance is increased efficiency, and in obtaining this in the petrol car, that is to say, in assuring better employment of the carburetted mixture, one of its greatest inconveniences, the unpleasant odour, will be prevented to a large extent. In this respect the improvement of the motor is allied closely with that of the carburetter, which should be made a subject of study, particularly with regard to its better adaptation to each type of motor. The progress typified by the design of the Krebs carburetter, produced by the Panhard firm and described on pp. 141 to 144, may be referred to by way of note. The respective influence of each quality of petrol spirit is another point claiming attention, and the variations in quality of the petrol put on the market during the last twelve months lend additional importance to this.

Without abandoning the petrol motor, there must be an endeavour to give it elasticity. The want of elasticity in a petrol motor is due to the two-fold fact that the same amount of carburetted mixture is admitted at each suction stroke, the volume of the cylinder being constant, and the proportion of this mixture can hardly vary because the proportions of the mixture and the degrees of its compression which ensure efficiency are very limited. The Krebs carburetter and the Chenard and Walcker and Soames regulating devices have improved matters greatly.

Other desirable improvements in
obviate the necessity of using cooling
easier. The Lanchester firm find
successful, and with regard to star
greatest simplicity on petrol-electric
The efficiency of transmission need
be made the object of comparative
according to the Chicago tests, is
petrol cars. This is rather low, thoug
conclusive tests to specify the relative
transmission, which comprise toothed
chainless systems. A very gradual cha
as long as there is not a mechanical m
with the complex part that this o
attention is being devoted in this c
that effort is so often expended ir
plate systems whose inefficiency a
commented upon already. The calc
that the motive power given to an
upon unreliable bases. In the forn
strains there are very dubious numer
friction in the axle-boxes, of the whee
mission gear, resistances due to bad r
it would be of general advantage if th
Long ago Deprez explained the meth
friction, and for other cases Forestier
the employment of Desdouits' dynamon
car previously furnished with a suffici
With regard to wheels, there cannot
respecting setting and dishing, their g
with chain traction, their effect in turn
diameter, the material for making spo
the inflation of pneumatic tyres. Unti
steering gear, but Bourlet seems to ha
p. 438). And there are other obscur
struction, each of which demands speci
be made. It was stated three years
as the most improved would in t
years be looked upon as being barbar

good in the case of motor cars produced within the last twelve months ?

What remains to accomplish in the construction of automobiles should not prevent a recognition of the importance of what already has been done in the short period of time since the renaissance of motorism. The automobile is a practicable road vehicle, whose compulsory stoppages on the road tend to become exceptions due to disorder in the ignition system, a hitch in the working of the pump, punctured tyre, etc., all these being so many causes of stoppage which can easily and even rapidly be set right. All the signs of the times go to prove that automobilism will enter completely into the customs of the day.

Axle Bearing Friction, 430
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